Function description

General

The machine is a time-controlled, constant-volume long-term ventilator for adults and children.

1 Basic principle

The machine communicates via a serial interface (CAN) and consists of the following assemblies:

- Control unit
- Electronic assembly
- Pneumatic assembly

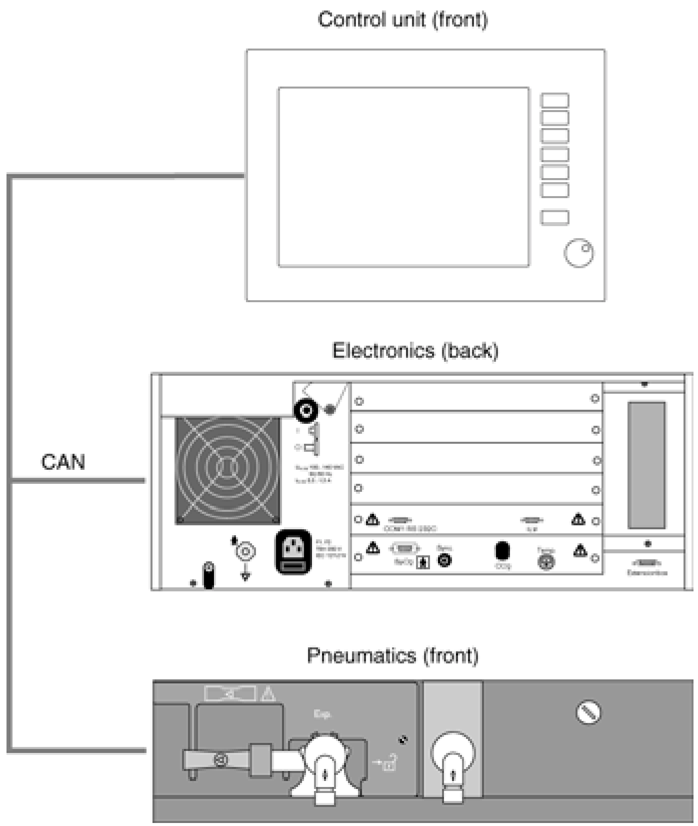


Fig. 1 Assemblies of the machine

1.1 Control unit

The control unit is the interface between the machine and the operator. The control unit is used to set parameters, it displays measured values, and generates warnings. The control unit comprises the following subassemblies:

- 15“ TFT display
- Membrane keypad
- Touchscreen with resistive touch
- Control knob
- Graphic Controller 8 PCB
- Connector PCB

1.2 Electronic assembly

The electronic assembly is the central control unit. The electronic assembly includes the CPU 68332 PCB, the CO2 Carrier PCB, the Processor Board PCB, the Power Supply PCB, and the power pack (Communication PCB, Pediatric Flow PCB, IFCO Carrier PCB, and SpO2 PCB are optional features).

1.3 Pneumatic assembly

The pneumatic assembly controls the pneumatic valves following preset ventilation parameters. The pneumatic assembly includes an independent microprocessor system and the valve control. The pneumatic assembly comprises the Pneumatic Controller PCB, the HPSV Controller AIR/O2 PCB, the PEEP valve, the mixer, the compressed-gas connection, the flow sensor, and the O2 sensor.

1.4 Simplified block diagram

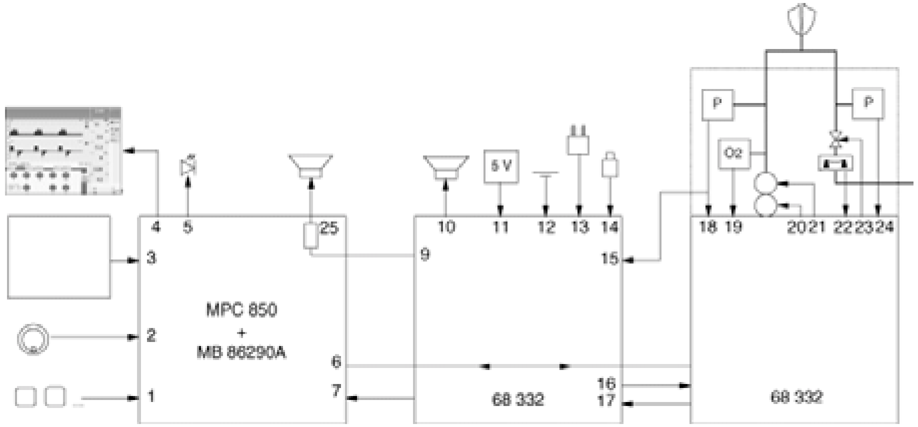


Fig. 2 Basic principle

1	Keys	13	Supply voltages

2	Control knob	14	Power switch
3	Touchscreen	15	Second inspiratory Paw
4	TFT display	16	Reset pneumatics processor and venting
5	Information LEDs and Alarm LEDs	17	Electronic processor reset and second loudspeaker alarm
6	CAN bus	18	Inspiratory Paw
7	Graphics processor reset	19	O2 sensor
8	Not applicable	20	FiO2 (HPSV mixer)
9	Loudspeaker with sound chip	21	AIR (HPSV mixer)
10	Second loudspeaker (piezo)	22	Flow sensor
11	Voltage monitoring (activates reset of the processors and the piezo)	23	Expiratory valve with PEEP
12	Rechargeable battery (Goldcap capacitor)	24	Expiratory Paw

2 Electronic assembly

2.1 CPU 68332 PCB

The CPU 68332 PCB is integrated in the electronic assembly of the machine. The CPU 68332 PCB includes an independent microprocessor system, two external interfaces, three internal interfaces, the loudspeaker control and a serial EEPROM.

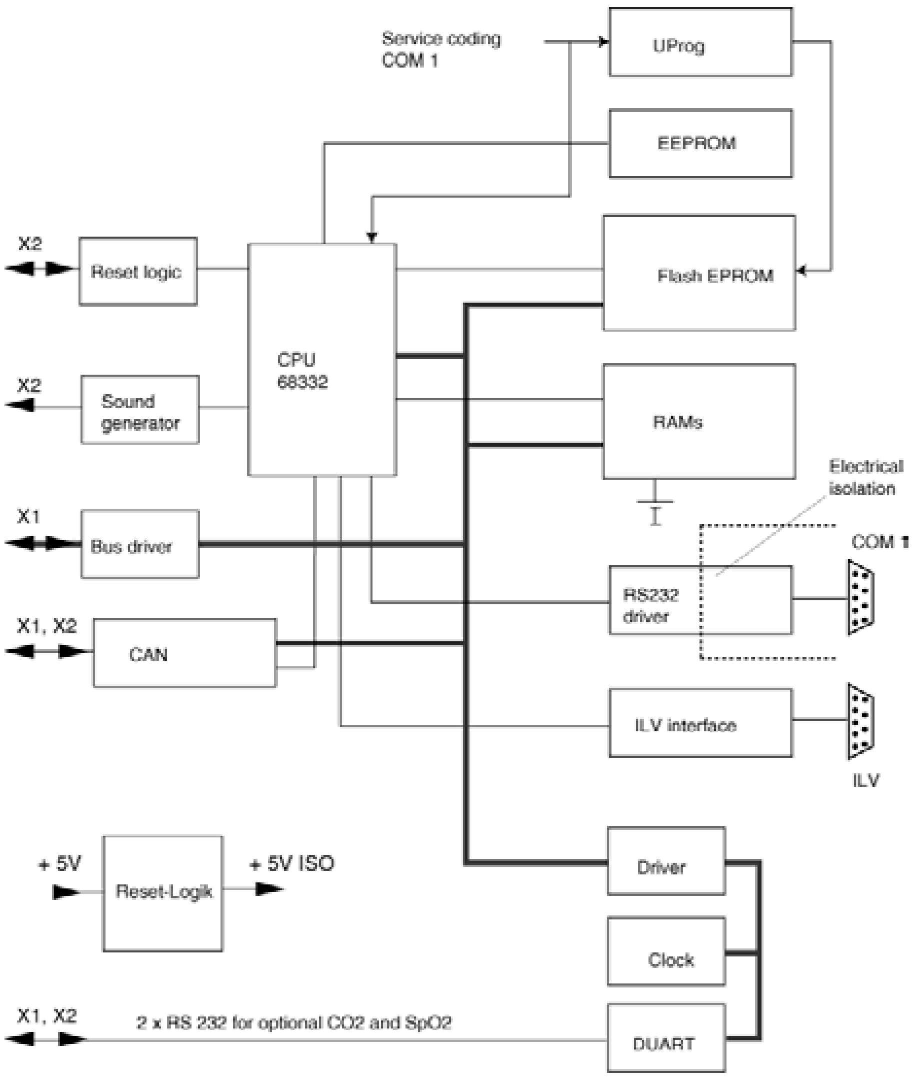


Fig. 3 Block diagram of the 68332 PCB

2.1.1 EEPROM

The EEPROM is connected to the synchronized, serial interface of the 68332. The EEPROM characterizes the machine (enabled options, serial number, etc.).

2.1.2 Microprocessor system

The microprocessor systems consists of a 68332 CPU, a 512 kB random-access memory (RAM), and a 1 MB electrically programmable and electrically erasable read-only memory (flash EPROM). The RAM is battery-buffered. When the battery is being replaced a Goldcap capacitor ensures voltage supply of the RAM. Programming of the flash EPROMs is only possible if the system identifies the “SERVICE-Q“ signal.

2.1.3 RS232 interface

The CPU 68332 PCB provides an RS232 interface in the Evita. The interface is labeled COM1. Optocouplers electrically isolate the RS232 interface from the machine.

2.1.4 ILV interface

The ILV interface allows for independent lung ventilation with two machines. The ILV interface is not electrically isolated. Pin 3 of the ILV interface is provided with a filler plug. This filler plug prevents confusion with the RS232 interface.

2.1.5 Driver

The driver adjusts the access times between the 68332 CPU, the clock and the DUART.

2.1.6 Clock

The clock makes sure that the current time is displayed. The clock is battery-buffered. This is to ensure that the clock is supplied with the required operating voltage after the device is switched off.

2.1.7 DUART

The DUART (Dual Universal Asynchronous Receiver/Transmitter) has two serial interfaces and digital inputs and outputs. The SpO2 module and the CO2 module are connected to the serial interfaces.

2.1.8 DC/DC converter

The DC/DC converter generates the voltage (+5V ISO) required for the interface. The input voltage of the DC/DC converter is +5V.

2.1.9 CAN interface

The CAN interface is a fast, serial interface. Via the CAN interface the control unit can communicate with the electronic and pneumatic assemblies. The transmission rate is 800 kbit/s.

2.1.10 Bus driver

Via the bus driver, the signals from the address bus, the data bus, and the control bus are transmitted to the motherboard. The 68332 CPU uses the bus driver to communicate with the optional printed circuit boards installed on the motherboard (currently the Pediatric flow PCB (optional Neoflow feature)).

2.1.11 Sound generator

The sound generator controls the loudspeaker in the control unit. The sound generator includes the sound volume control and the tone generation of the loudspeaker. The sound volume is controlled by the DUART.

2.1.12 Reset logic

The CPU 68332 PCB uses a reset signal to reset (restart) the control unit and the pneumatic assembly. A reset is also triggered when the +5 V operating voltage is not reached (too low or too high).

The pneumatic assembly can also send a reset signal to the CPU 68332 PCB, thus resetting the CPU 68332 PCB. The reset logic controls and displays the resets.

2.2 CO2 Carrier PCB

The CO2 Carrier PCB is integrated in the electronic assembly of the Evita. The printed circuit board includes the mount and the electrical isolation of the CO2 module and the SpO2 module, the mains voltage failure logic, the temperature measurement and the voltage monitoring.

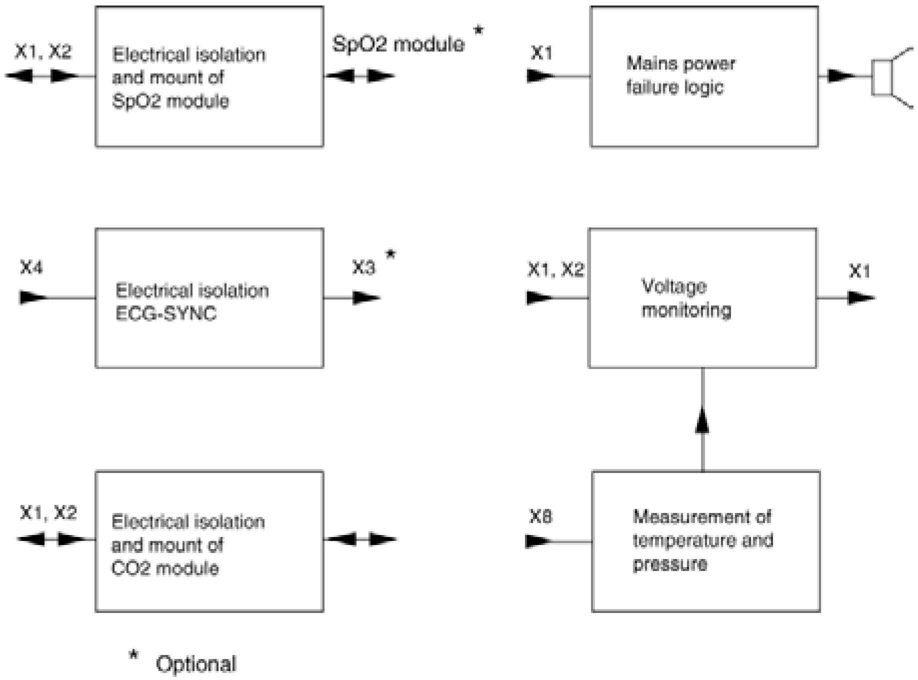


Fig. 4 Block diagram of the CO2 Carrier PCB

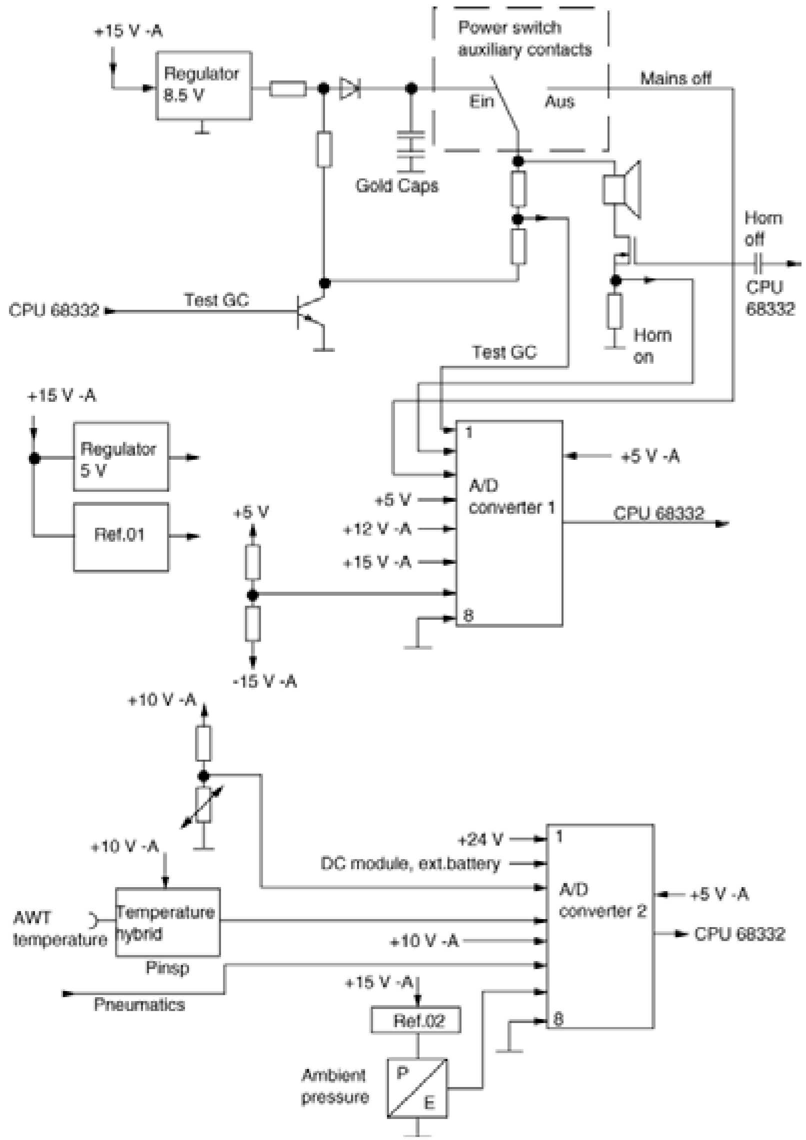


Fig. 5 Block diagram of the CO2 Carrier PCB, part 1

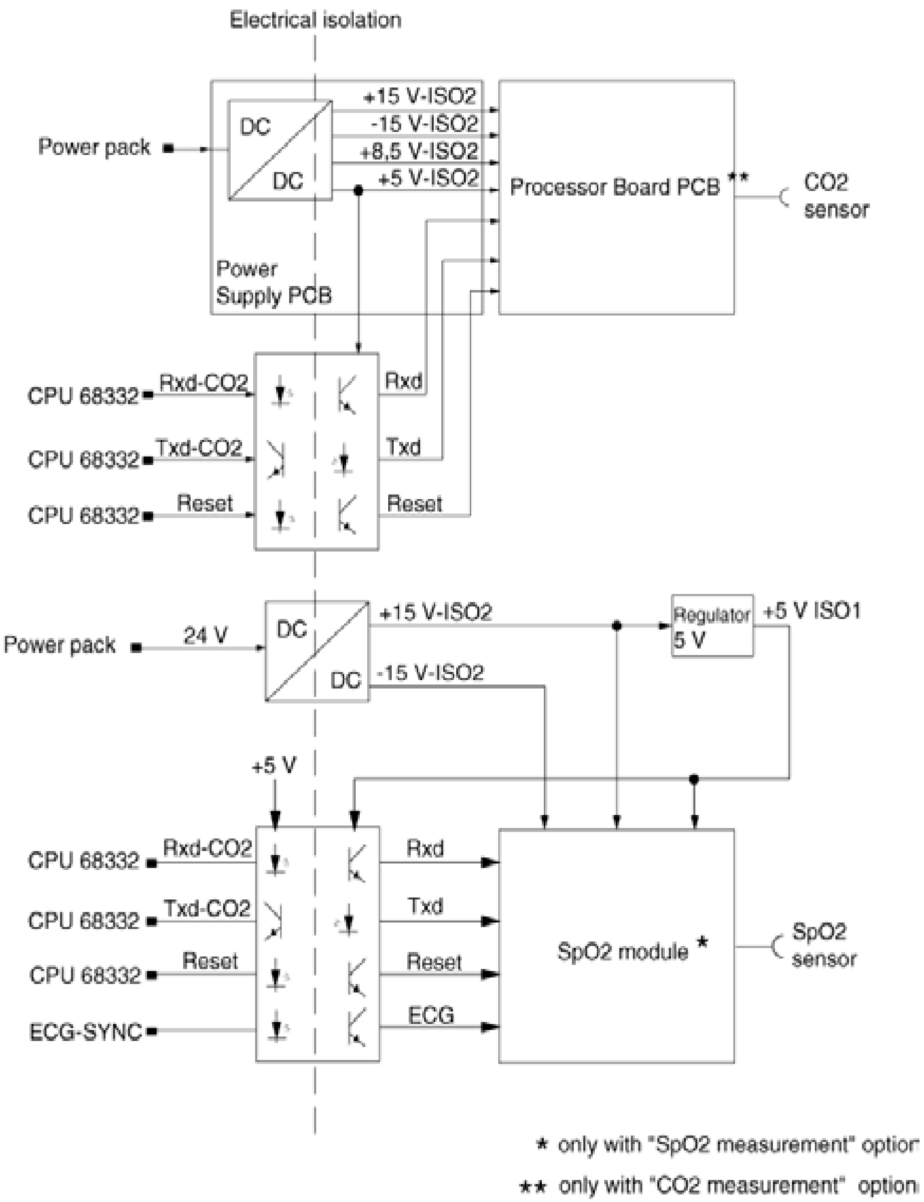


Fig. 6 Block diagram of the CO2 Carrier PCB, part 2

2.2.1 Electrical isolation

Optocouplers electrically isolate the printed circuit boards from the interfaces. The printed circuit board is provided with plug-in contacts. The SpO2 and CO2 modules are plugged into these plug-in contacts. The X3 connector is part of the optional “SpO2“ module and is not equipped.

2.2.2 Mains voltage failure logic

The mains voltage failure logic monitors the mains voltage supply. In the event that a mains voltage failure occurs while the machine is operating an audible alarm will sound.

2.2.3 Voltage monitoring

The microprocessor monitors the following voltages:

- 15 V
- +10 V
- +24 V
- +12 V
- +5 V

All voltages are present at a voltage divider. An A/D converter reads out the respective voltages. The CPU 68332 PCB reads out the AD converter.

2.2.4 Measurement of temperature and pressure

A temperature sensor measures the current temperature. The temperature sensor is a thermistor (NTC). A temperature hybrid outputs the respective analog voltage value. The output signal from the temperature hybrid is transmitted to an A/D converter which converts the analog voltage value in a digital value. The CPU 68332 PCB reads out the digital value.

A pressure sensor measures the current ambient pressure. The output signal from the pressure sensor is transmitted to an A/D converter which converts the analog voltage value in a digital value. The CPU 68332 PCB reads out the digital value.

2.3 CO2 measurement

The CO2 measuring system comprises three modules:

- CO2 sensor
- Processor Board PCB
- Power Supply PCB

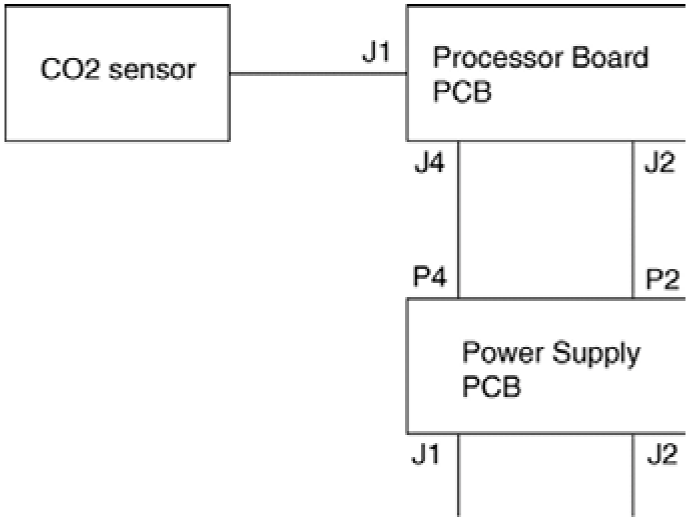


Fig. 7 Block diagram of the CO2 measurement

2.4 CO2 sensor

The CO2 sensor comprises the CO2 measuring unit and a microprocessor system. A lamp generates a light spectrum up to 4.5 micrometers. This light spectrum is transmitted via the cuvette and two sapphire lenses to detectors. The detectors emit electrical signals depending on the CO2 concentration. The microprocessor analyzes these signals and transmits them to the Processor Board PCB via an RS232 interface.

The CO2 measuring unit is kept at a constant temperature to avoid condensation.

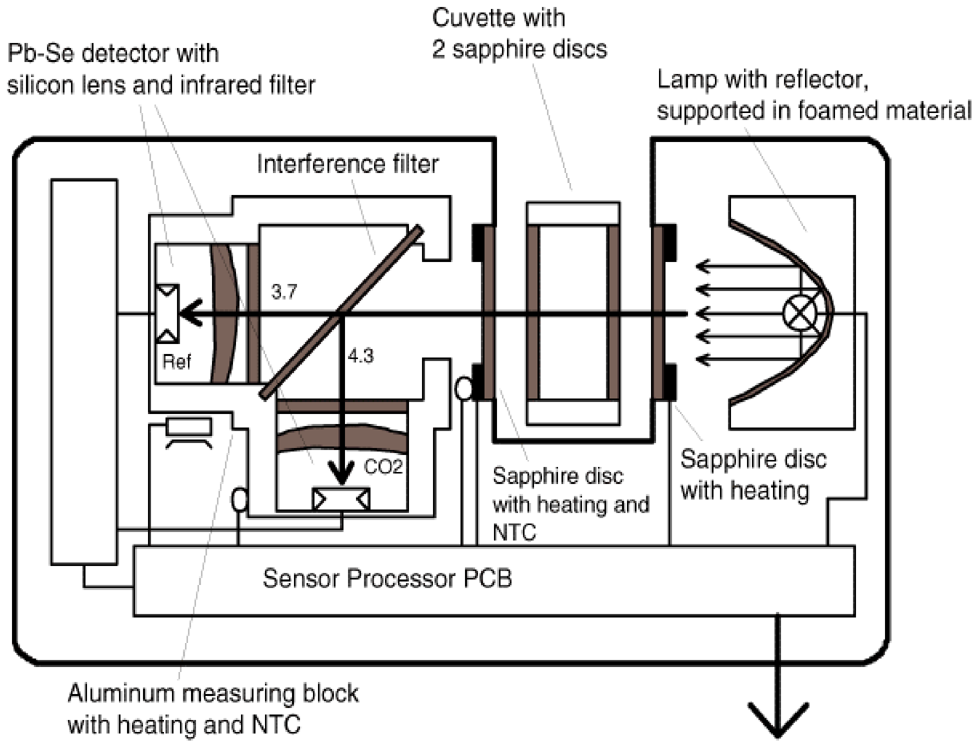


Fig. 8 Sectional view of the CO2 sensor

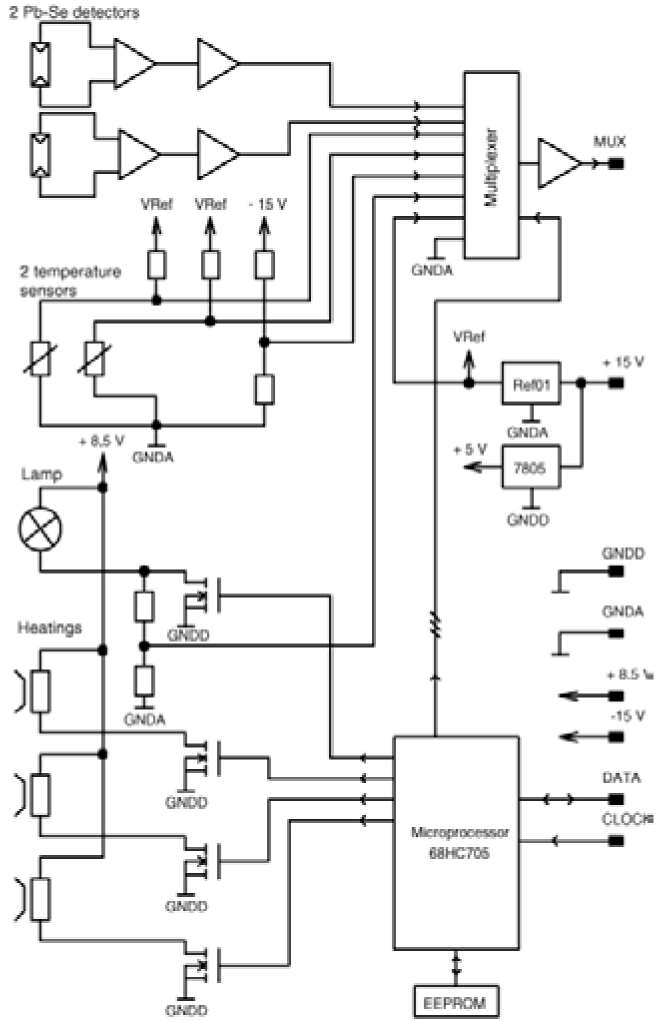


Fig. 9 Block diagram of the CO2 sensor

2.5 Processor Board PCB

The Processor Board PCB controls the heating (CO_2 measuring unit) and the measured-data transfer of the CO_2 sensor.

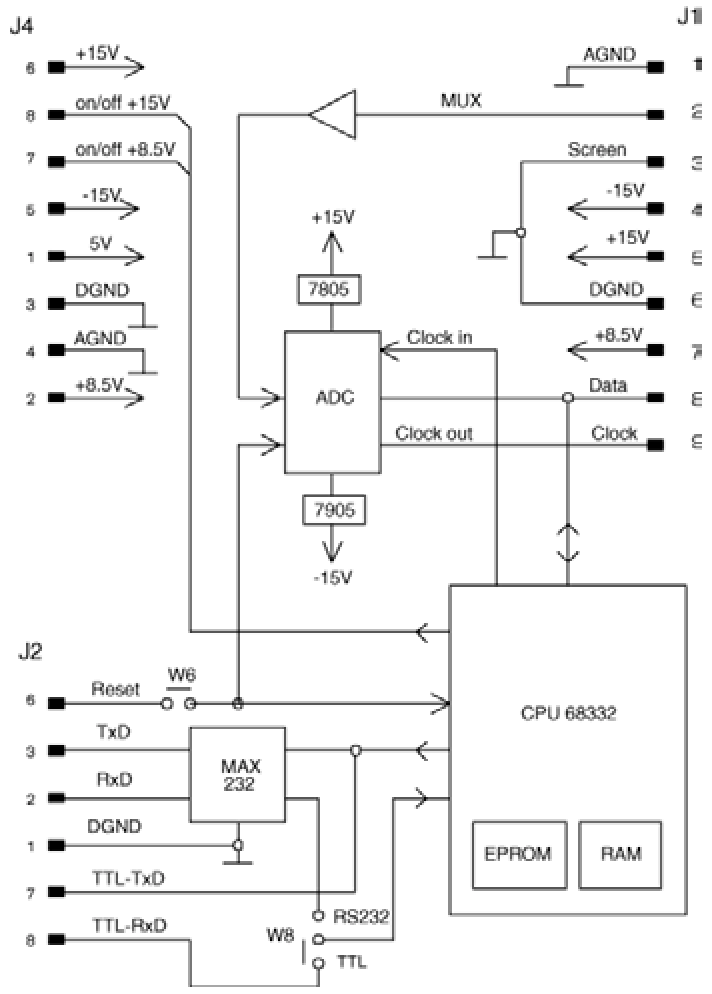


Fig. 10 Block diagram of the Processor Board PCB

2.6 Power Supply PCB

The Power Supply PCB provides the supply voltages for the Processor Board PCB and the CO2 sensor. The supply voltages are electrically isolated from the machine. The CO2 measured values are transmitted to the CPU 68332 PCB via the Power Supply PCB.

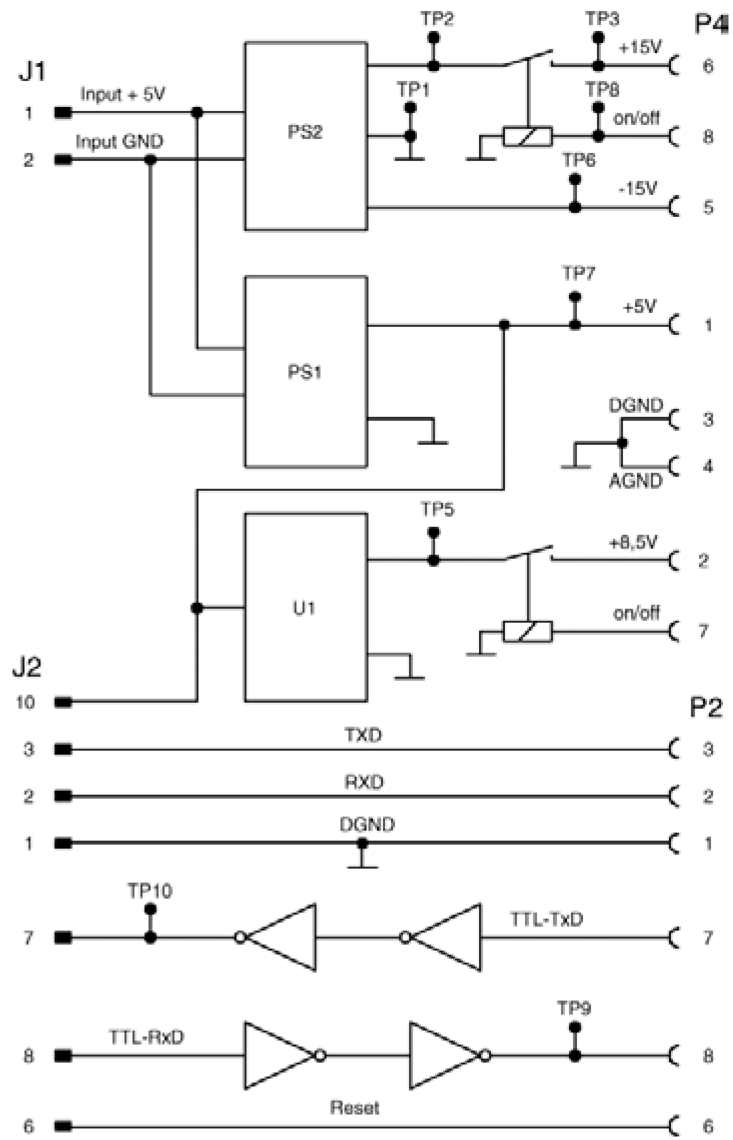


Fig. 11 Block diagram of the Power Supply PCB

2.7 Power pack

The switched-mode power pack provides the following output voltages:

- +24 V
- +15 V
- –15 V
- +12 V
- +5 V

The output voltages are short-circuit-proof.

2.7.1 DC module

The DC module makes sure that the machine is powered in the event of a mains voltage failure.

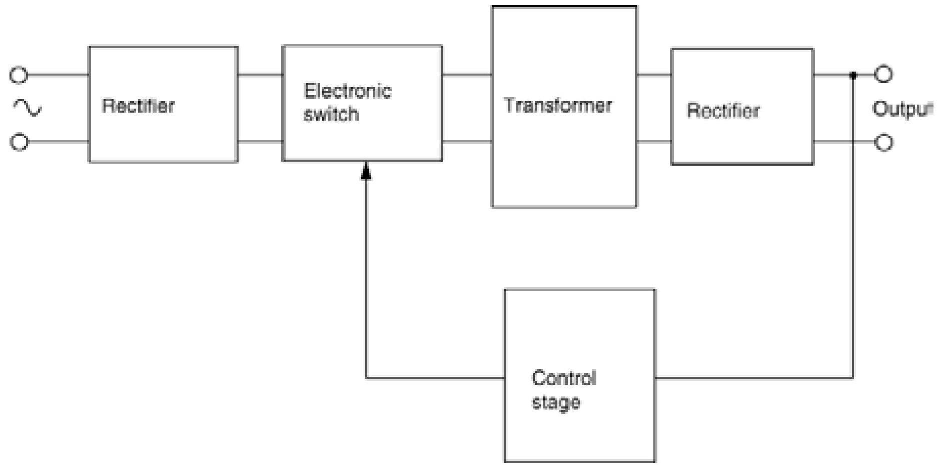


Fig. 12 Schematic circuit diagram of the switched-mode power pack

2.8 Graphic Controller 8 PCB

The Graphic Controller 8 PCB is fitted to the control unit. Connection to the electronic assembly is made via a 15-pin SUB-D connector.

The printed circuit board includes an independent processor system, the voltage supply of the control unit, the interface to the electronic assembly and the display control.

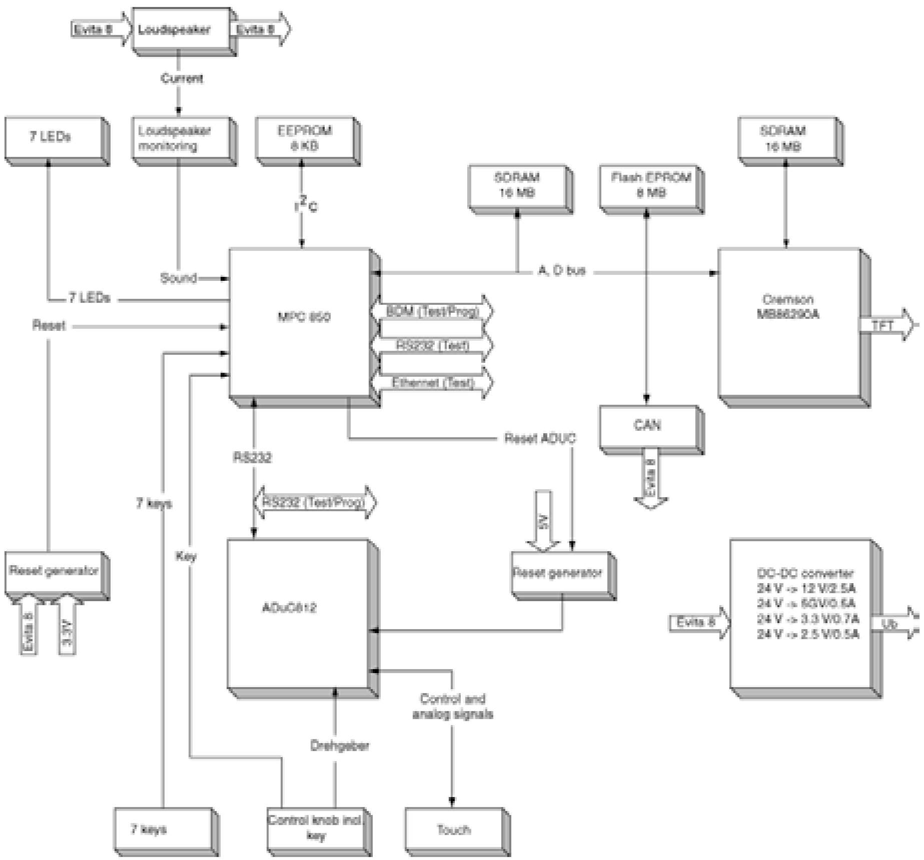


Fig. 13 Block diagram of the Graphic Controller 8 PCB

2.8.1 MPC 850

The power PC “MPC 850“ has a maximum clock frequency of 80 MHz. The bus frequency rate is 40 MHz.

The MPC 850 contains the following components:

- 32-bit RISC microprocessor
- 2 kB data cache, 1 kB program cache
- MMU (Memory Management Unit)
- On-chip emulation debug mode
- Timer, bus monitor, watchdog, interrupt controller, clock synthesizer, JTAG interface
- Memory controller
- CPM (Communications Processor Module)
- 4 baud rate generators
- 2 SCC (Serial Communication Controller)
- 2 SMC (Serial Management Controller)
- 1 SPI
- 1 I2C
- 3.3 V operation with 5 V-tolerance inputs

2.8.2 SDRAM

The RAM has a memory area of 16 MB. This memory area is provided by two SDRAMs with 4 MB x 16 bit each.

2.8.3 Flash EPROM

The program of the control unit is stored in the flash EPROM. It has a total capacity of 8 MB. The flash EPROMs are connected to the MPC 850 through a

logic circuit in order to avoid unintentional changing of the contents. The logic circuit avoids that data is written without a connector being connected to the “COM1“ interface.

2.8.4 LED control

The seven keys on the membrane keypad have a status LED each. In order to activate a status LED, the MPC 850 sends signals to a parallel port. This parallel port triggers the respective driver of the status LED.

2.8.5 Key inputs

All keys are connected to ground. For interference suppression purposes, the key inputs are provided with ferrite cores and suppressor capacitors.

The control knob key and all other key are connected to the MPC 850.

2.8.6 Loudspeaker monitoring

The MPC 850 monitors the current across the loudspeaker. To this end, a 5-ohm resistor is looped in the loudspeaker lead as a combination of eight 10-ohm resistors. Capacitors tap the voltage present at the 5-ohm resistor and supply it to a differential amplifier. The amplified signal is available at a comparator.

2.8.7 Reset generator

The 3.3-V reset generator DS1819A delivers the reset signals for the MPC 850.

2.8.8 CAN controller

The CAN controller 82527 is connected to the MPC 850 through level converters. The CAN controller is supplied with 5 V.

2.8.9 ADuC 812

The microcontroller ADuC 812 controls the control knob and the touchscreen.

Rotary transducer input

The rotary transducer supplies two signals that are phase-shifted by 90 degrees. The microcontroller ADuC 812 scans both signals periodically (at approx. 1 ms period duration) thus determining the position of the rotary transducer.

Touchscreen control

The glass pane used on the control unit is coated and conductive. In front of it, there is a foil which is also coated and conductive. The foil’s coating resistance is approx. 1 kohm. Electrodes are attached to the foil (at the top and bottom) and to the glass pane (at the left and right).

When a finger touches the glass pane, the front foil is pressed against the glass pane thus creating a conductive connection.

The position of the finger is calculated as follows:

A current flows from top to bottom. The glass pane is switched to high resistance. The voltages are measured from top to bottom. The conductive, coated foil functions as a voltage divider the tap point of which is formed by the “contact point“ of the finger. The Y coordinate is determined by measuring the voltage.

Now the foil becomes high-resistant and a current flows across the glass pane from the left to the right instead. The X coordinate is determined by measuring the voltage.

The glass pane has a 8-wire design. That means that two electrodes each are attached to the edges. Changes in resistance on the glass pane itself or in the leads have no influence on the measurement result. A 4-wire measurement allows a current to flow across two electrodes, the reference voltage is then measured at the other two electrodes.

2.8.10 Graphic controller

The graphic controller MB86290A generates graphic signals and includes character operations. The graphic controller is connected to the MPC 850, it occupies an address area of 64 MB. The output signals are analog. The video memory has 16 MB.

2.8.11 Voltage supply

The control units uses the 24 V supplied from the power pack to generate the following voltages:

- 12 V (15“ TFT display), can be switched off with MPC 850
- 5 V (ADuC 812)
- 3.3 V (MPC 850)
- 2.5 V (graphic controller)

2.8.12 Switched-mode regulator

The switched-mode regulator (DC/DC converter) converts the 24 V into 12 V. A second switched-mode regulator (DC/DC converter) converts the 24 V into 5 V.

2.8.13 Series regulators

Two series regulators filter any interference from the DC/DC converter. As a result, the voltages (3.3 V and 2.5 V) do not receive any clock signals from the DC/DC converter.

2.8.14 Comparators

The comparators make sure that the 5-V converter only starts operating at an operating voltage of approx. 17 V or higher.

2.9 Communication PCB (optional)

The Communication PCB is integrated in the electronic assembly of the machine. The printed circuit board includes an independent microprocessor system, the voltage supply of the interfaces, an internal CAN interface, an external CAN interface, two RS232 interfaces and two analog outputs.

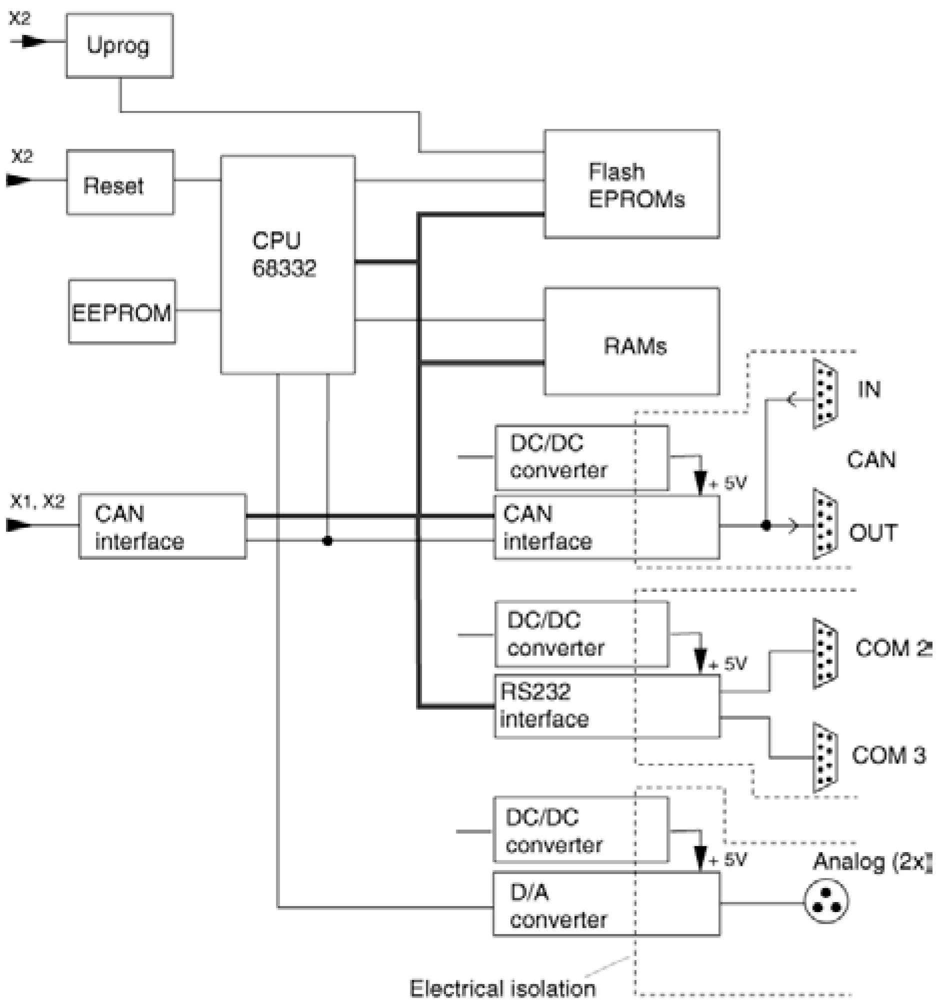


Fig. 14 Block diagram of the Communication PCB

2.9.1 Microprocessor system

The microprocessor system comprises the 68332 CPU, one 512-KB RAM, and one 1-MB flash EPROM (electrically programmable and erasable read-only memory).

2.9.2 Uprog

Uprog generates the voltage required for programming the flash EPROMs. An enable logic prevents unintentional supply of the programming voltage to the flash EPROMs.

2.9.3 Reset

The reset logic generates a defined reset after power-up. The CPU 68332 can be reset by the CPU 68332 PCB.

2.9.4 CAN interfaces

The Communication PCB is not connected to the data bus of the CPU 68332 PCB. The data are transmitted via an internal CAN interface (Controller Area Network – fast, serial interface). The external CAN interface is electrically isolated from the machine. Electrical isolation is made by means of optocouplers.

2.9.5 RS232 interfaces

The Communication PCB provides an RS232 interface in the machine. The interfaces are labeled COM2 and COM2. The interfaces are electrically isolated from the machine. Electrical isolation is made by means of optocouplers.

2.9.6 Analog outputs

The analog outputs supply voltages between 0 V and 4.095 V. The assignment of analog outputs is freely selectable. The resolution of the output voltage is 1m V per bit.

2.9.7 DC/DC converter

The DC/DC converters generate +5V ISO each for the voltage supply of the interfaces. The input voltages of the DC/DC converters are +5 V.

2.9.8 EEPROM

The EEPROM stores internal data of the interface. The EEPROM has a 2 kB capacity.

2.10 Pediatric Flow PCB

The Pediatric Flow PCB is integrated in the electronic assembly. The printed circuit board has two flow measuring channels for connection of the Babylog flow sensor, one four-channel multiplexer, one 12-bit A/D converter, and one interface to the CPU 68332 PCB.

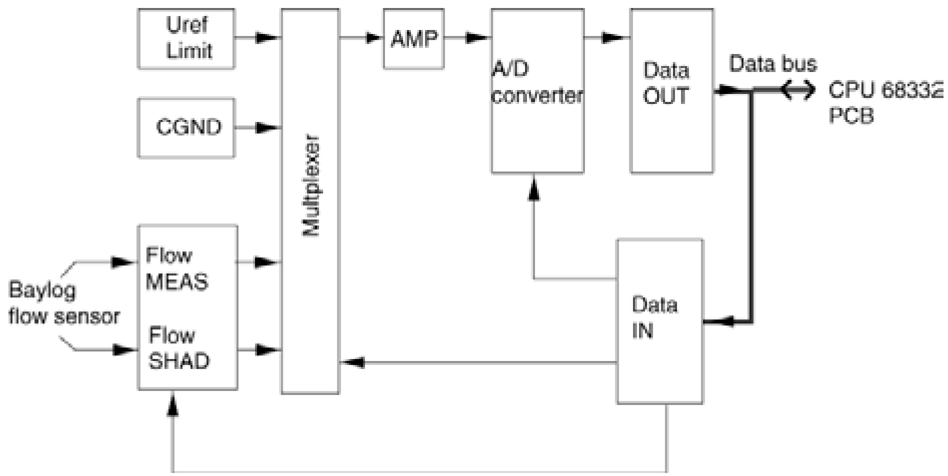


Fig. 15 Block diagram of the Pediatric Flow PCB

2.10.1 Flow measurement

The Babylog flow sensor measures the flow. The Babylog flow sensor is equipped with two measuring wires. One measuring wire is covered by a plastic bar, the Babylog flow sensor recognizes the direction of the flow. A measuring bridge analyzes the flow.

2.10.2 Multiplexer

The multiplexer consists of four analog-value selectors. The software controls the analog-value selectors. The multiplexer transmits the flow sensor measurement signals “CGND“ and “UREF LIMIT“ to a buffer (AMP). Then the measurement signals are transmitted to an A/D converter (ADC).

2.10.3 A/D converter

The input voltage of the A/D converter ranges from 0 V to 10 V. The A/D converter converts the flow measurement signals into digital data. The CPU PCB controls the A/D converter and the multiplexer via an interface (DATA OUT, DATA IN). The voltage drop across the multiplexer, the buffer and the A/D converter is measured using the “UREF LIMIT“ reference voltage and can be taken into account when measuring the flow.

2.11 IFCO Carrier PCB for additional optional features

The IFCO Carrier PCB functions as carrier board for other optional features; it supports the nurse call and Remote Pad (cable remote control) functions and one additional ambient pressure sensor (optional).

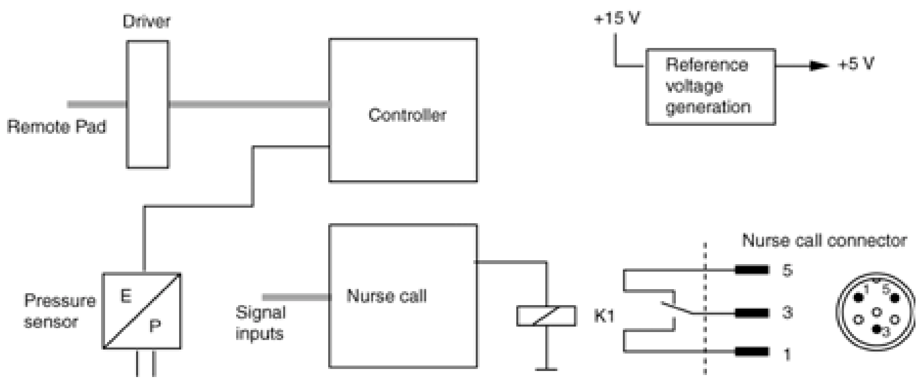


Fig. 16 Block diagram of the IFCO Carrier PCB

2.11.1 Nurse call

The nurse call transmits top-priority alarms (!!!) displayed on the screen to, e.g., a central station. An alarm is also transmitted if the internal loudspeaker for audible alarms fails. The alarm is reset automatically as soon as the cause of the alarm disappears. The alarms are suppressed during the boot phase (start phase of the device).

The central station alarm signaling is carried out by relay contacts. The alarm status can be determined by scanning these relay contacts. An alarm is considered to be triggered if contacts 3 and 5 of the nurse call connectors are closed by the relay contacts. These relay contacts are electrically isolated from the rest of the electronics. A bistable relay is used in order to keep this alarm signaling function active even when the power supply fails.

The nurse call function monitors the contacts of the power switch thus being able to detect whether the device is switched on or off. A power failure in the device can thus be detected. This alarm (power failure) can be cancelled by switching the device off. However, the device must be switched off within a defined time window. This time window is dependent on the charge status of specific capacitors. The time window is typically 2 minutes.

2.11.2 Remote Pad

The Remote Pad is a cable remote control that is connected to the IFCO Carrier PCB. The Remote Pad has 6 key to control the ventilator. The Remote Pad is also provided with alarm LEDs. The inputs and outputs of the Remote Pads are short-circuit protected and protected against inadvertent wrong connections.

2.11.3 Pressure sensor (optional)

The measured value supplied by the ambient pressure sensor on the IFCO Carrier PCB is evaluated by the safety software. This measured value is used to monitor the ambient pressure sensor on the CO2 Carrier PCB.

2.12 Pneumatic Controller PCB

The Pneumatic Controller PCB is located in the pneumatic assembly. The printed circuit board provides the following functions:

- Supply pressure measurement
- Inspiratory and expiratory airway pressure measurement
- Esophageal pressure measurement
- Measurement of the flow
- Measurement of the O2 concentration in the respiratory gas
- Fan monitoring
- Solenoid valve control
- PEEP valve control
- Interface to the HPSV Controller PCBs
- CAN interface
- 68332 CPU with RAM and flash memory
- Serial EEPROM for storage of device configuration

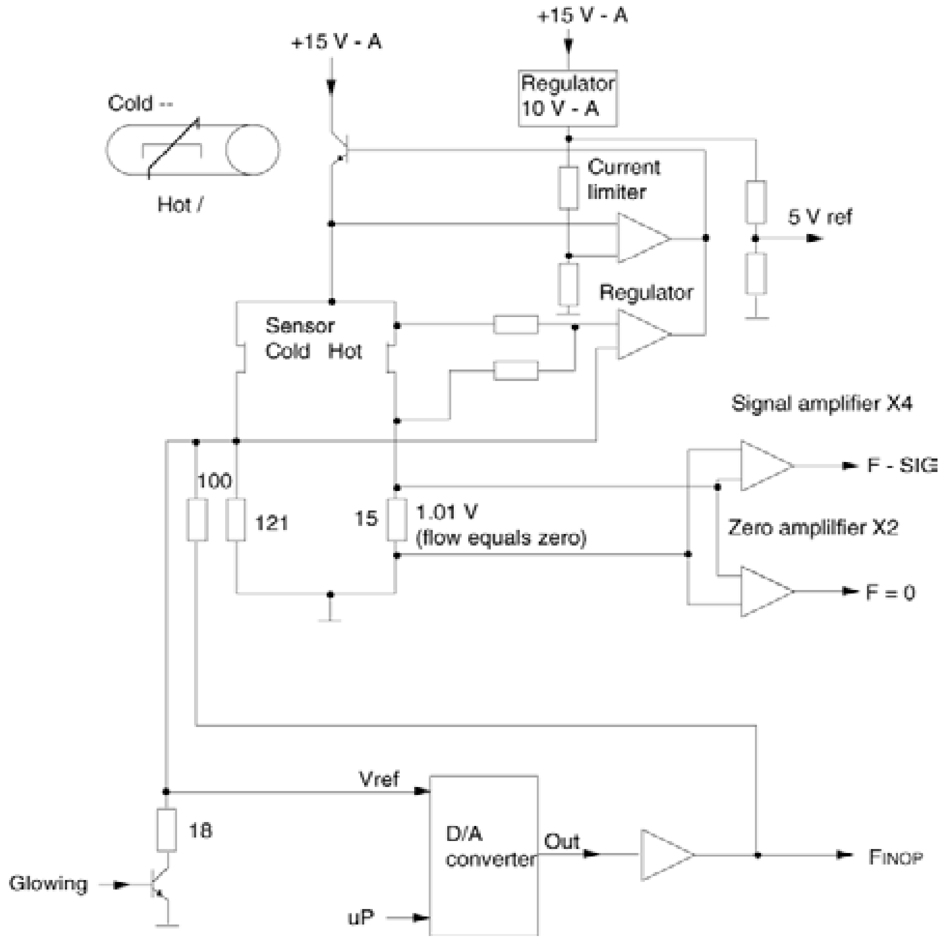


Fig. 17 Flow measurement, Pneumatic Controller PCB

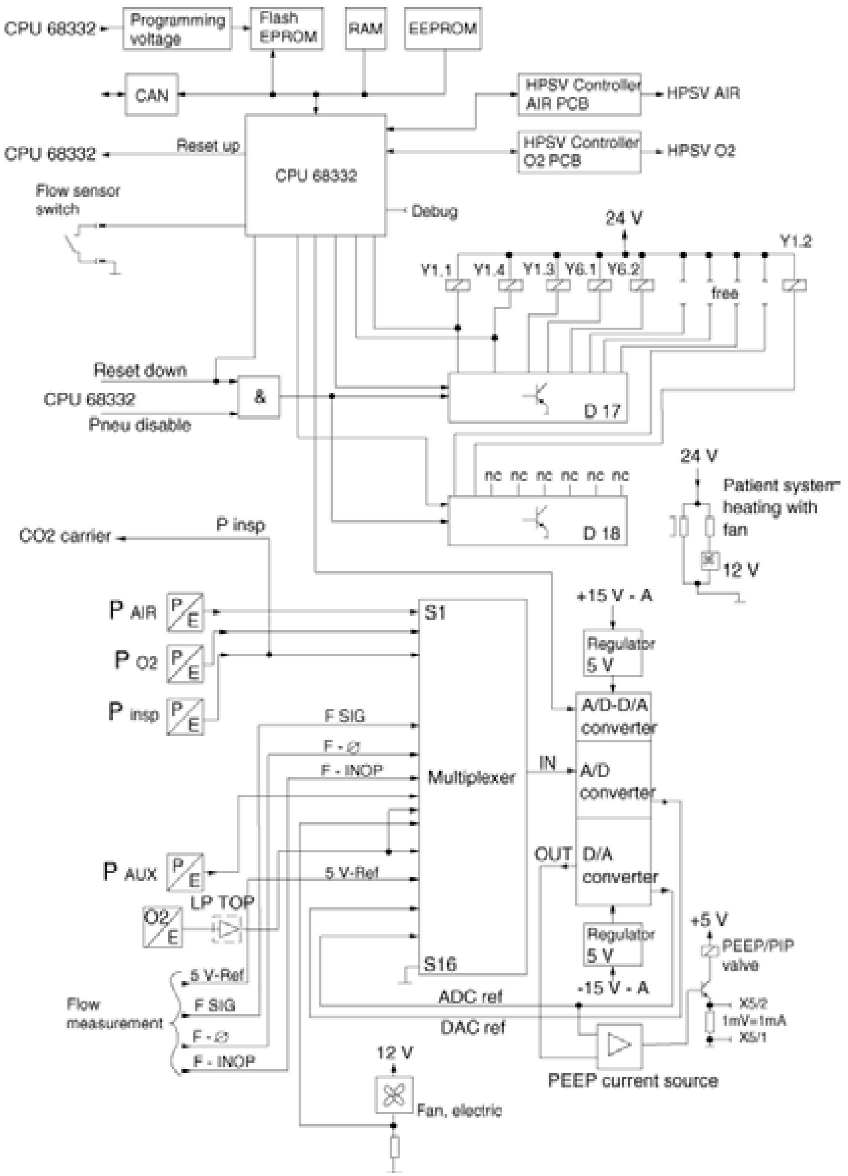


Fig. 18 Pneumatic Controller PCB block diagram

2.12.1 Pressure measurement

Two pressure sensors measure the pressure. The respective pressure sensors measure the pressure during the inspiratory phase and the expiratory phase. The airway pressure signals are transmitted to a multiplexer. A zero calibration of the pressure sensors is carried out automatically every three minutes.

2.12.2 Flow measurement

The flow sensor works according to the principle of a constant-temperature hot-wire flowmeter. Respiratory gas flows along a very thin, electrically heated platinum wire in a measuring tube. The wire is heated to a temperature of 180 degrees centigrade and kept at this temperature with a closed-loop control system. If gas flows past this wire, heat is dissipated. The larger the gas volume per time unit flowing past, the higher the heat dissipation. The heating power required to keep the wire at a constant temperature is a measure of the gas flow.

2.12.3 Cleaning of the flow sensor

The control for cleaning (glowing) of the flow sensor supplies a defined current to both measuring wires. During calibration the measuring wires begin to glow and burn any impurities. The sensor is cleaned when pressing the “flow calibration“ key or automatically after

drug nebulization. The cleaning process occurs during the next inspiratory phase or after 15 seconds at the latest.

2.12.4 Oxygen measurement

The O2 sensor works according to the galvanic cell principle. Oxygen molecules contained in the gas mixture to be measured diffuse through a plastic diaphragm into the electro-chemical cell and are reduced at the noble metal electrodes. At the same time a base electrode is being oxidized. The base electrode is spent by the oxidation process and thus determines the life of a sensor. The current flowing through the cell is proportional to the oxygen partial pressure in the gas mixture to be measured.

Provided the pressure and temperature of the gas mixture to be measured are kept constant, the measured value will be directly proportional to the oxygen partial pressure. The O2 amplifier on the O2 Top PCB is mounted externally on the inspiratory block The output signal is transmitted to the O2 Contact PCB via spring contacts. From there the output signal is transferred to the Pneumatic Controller PCB. The O2 cell is also connected to the O2 Top PCB via spring contacts.

2.12.5 Fan monitoring

At the front panel of the machine a fan is mounted to limit the temperature and the O2 concentration in the electronic unit of the pneumatic assembly in case of failure. The electronics monitors the fan.

2.12.6 Multiplexer

The multiplexer consists of 16 analog-value selectors. The software controls the analog-value selectors. The multiplexer routes the measurement signals from the pressure sensors, the O2 amplifier, the FAN UREF and the flow sensor to a buffer. The output signals of the buffer are then available at an A/D converter.

2.12.7 Solenoid valves

Two power drivers control the solenoid valves. A comparator monitors the power driver outputs for the nebulizer and the O2/Air switchover. The power drivers can be switched off from the electronic unit.

2.12.8 PEEP valve control

A voltage-controlled current source with power MOSFET controls the PEEP valve.

A quad operational amplifier serves to adapt the D/A converter output signal to the current range of the PEEP valve. The CPU controls the D/A converter.

The PEEP valve control is calibrated to the PEEP valve. The calibration data are stored in the serial EEPROM.

2.12.9 HPSV interface

The status lines of the HPSV Controller PCB are led to the Pneumatic Controller PCB via the pneumatics motherboard. Two bus drivers transmit the data to the data bus of the CPU. The data are transmitted to the HPSV Controller PCB by two power drivers. The data are accepted by “power swing“ of the respective chip-select pin.

2.12.10CAN interface

The CAN interface comprises a CAN controller and a series-connected driver. The CAN controller is directly connected to the data bus of the CPU. The control unit, the electronics and the pneumatics communicate via a CAN interface. The transmission rate is 1 Mbit/s.

2.12.11Microprocessor system

The microprocessor system on the Pneumatic Controller PCB consists of a 68332 CPU, a 256 kByte flash EPROM (electrically programmable and erasable read-only memory) and a 256 kByte RAM.

2.12.12Serial EEPROM

The serial EEPROM stores the data of the pneumatics. The EEPROM has a 128 Byte capacity.

2.13 HPSV Controller PCB

The pneumatic assembly contains two identical HPSV Controller PCBs. The board slot determines which of the boards is assigned to O2 and AIR. The HPSV Controller PCB comprises the following functions:

- Microcontroller with EPROM and RAM
- A/D converter for measurement of supply pressure
- D/A converter for current set-point specification
- Closed-loop circuit for current control
- Power transistor (power source)

Note: The characteristic of the HPSV cartridge is stored in the cartridge itself. The HPSV Controller PCB reads out this characteristic.

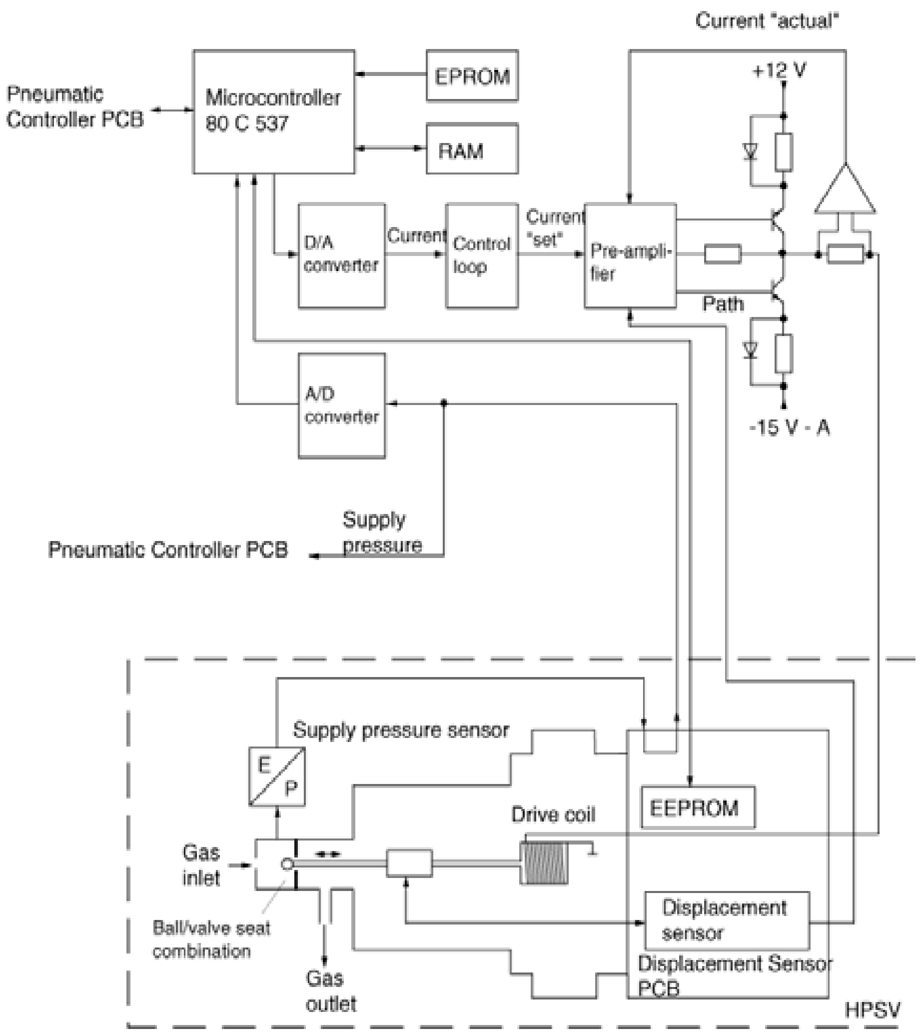


Fig. 19 HPSV Controller PCB with HPSV

3 Pneumatic assembly

The machine needs a driving gas pressure (AIR and O2) of 2.7 to 6 bar.

The pneumatic assembly consists of the following subassemblies:

- Dräger gas connection block/FAS gas connection block
- Parallel mixer or mixer block
- Pressure sensors
- PEEP/PIP valve
- Inspiration block
- Patient system

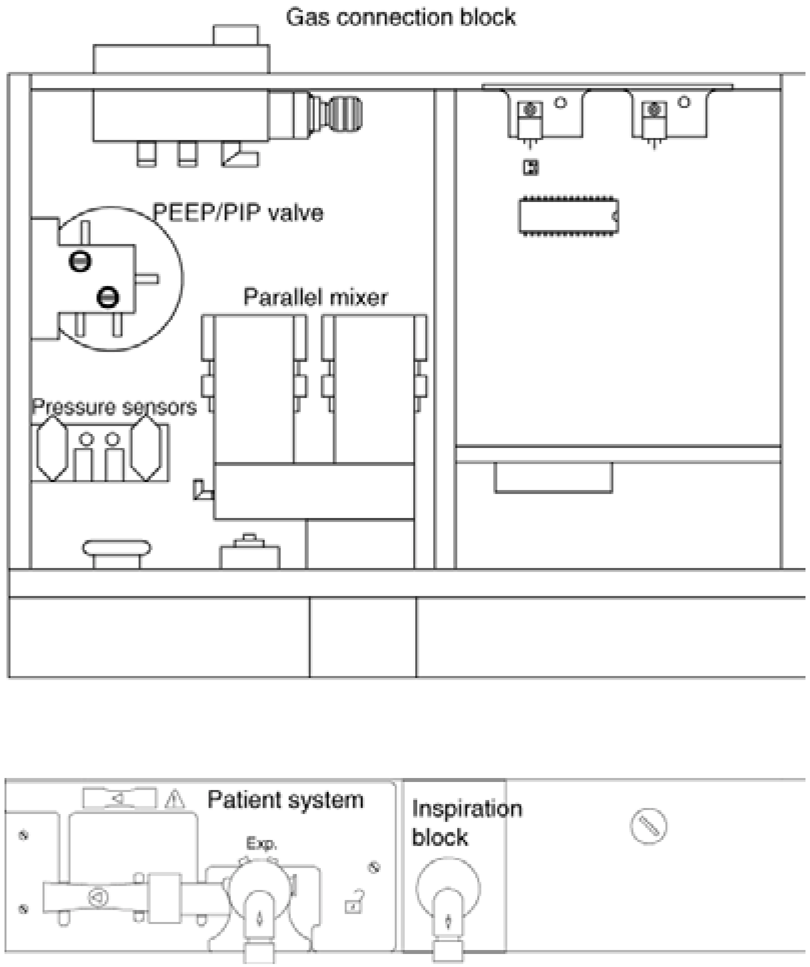


Fig. 20 Layout of the pneumatic subassemblies

3.1 Gas connection block

The gas connection block comprises the “O2“ gas connection (M12x1 female) and the “compressed air“ connection (M 20x1.5 male). The following connections are available: NIST, DISS (USA) and DIN. The connections are fitted with filters F1.1 and F1.2 (metal fiber web). The check valves D1.1 (AIR) and D1.2 (O2) prevent the gas from flowing back into the central gas supply system.

The pressure regulators DR1.1 and DR1.2 are set to 2 bar. The control gas flows past the DR1.1 to the 3/2-way valve Y1.1, from there to the emergency valve Y1.3, to the PEEP/PIP valve Y4.1 and finally to the emergency valve Y3.1.

The gas also flows to the expiratory pressure sensor S6.2 (purge flow) via the restrictor R1.1 (0.08 L/min).

Gas flows to the nebulizer via the 3/2-way valve Y1.4, if appropriately adjusted.

In the event of “AIR“ supply failure, the machine will switch over to O2 supply (O2 switchover function)

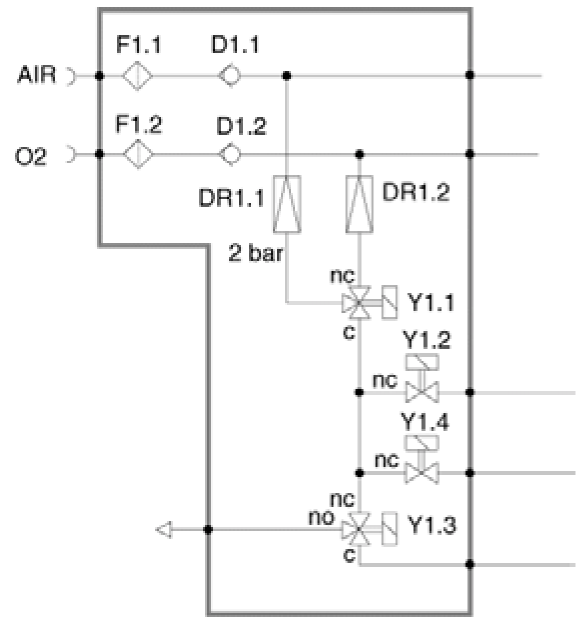


Fig. 21 Functional diagram of the gas connection block

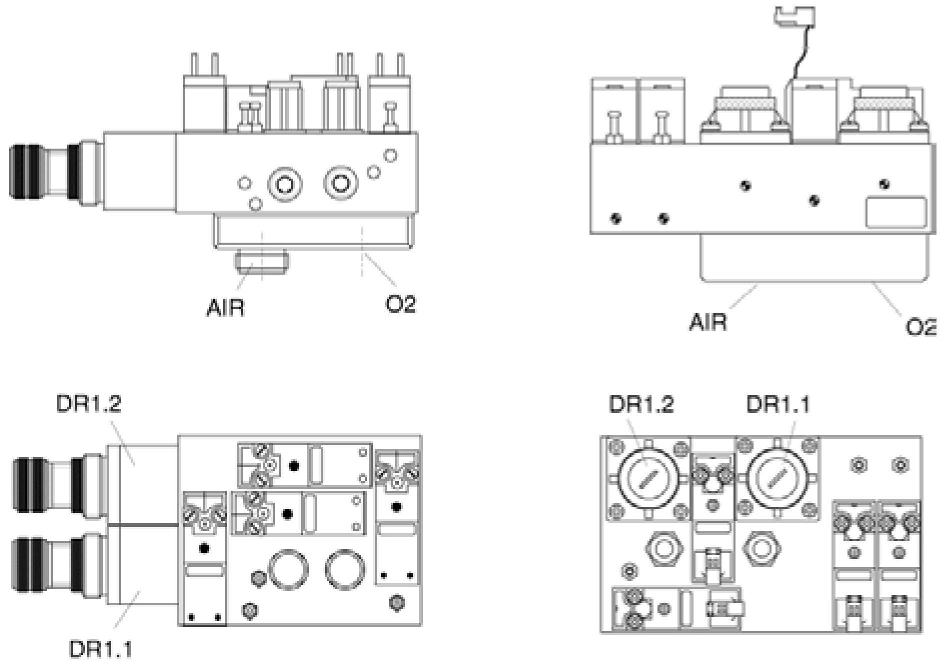


Fig. 22 Dräger gas connection block (left) and FAS gas connection block (right)

3.1.1 Characteristics of various gas connection blocks

Characteristics of the FAS gas connection block:

- Connector plate
- Pressure regulator

Legend

DR1.1	AIR pressure regulator
DR1.2	O2 pressure regulator
Y1.1	3/2-way solenoid valve, O2/AIR
Y1.2	3/2-way solenoid valve pressure, sensor calibration inspiration

Y1.3	3/2-way solenoid valve, venting
Y1.4	3/2-way solenoid valve, nebulizer

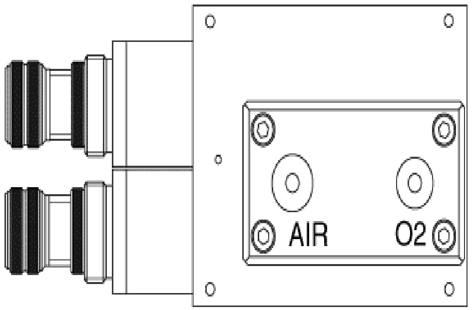
The gas connection blocks are interchangeable since their mounts for attaching to the machine are identical.

External distinguishing feature of the “Dräger gas connection block“:

- four fixing screws

External distinguishing feature of the FAS gas connection block:

- two fixing screws



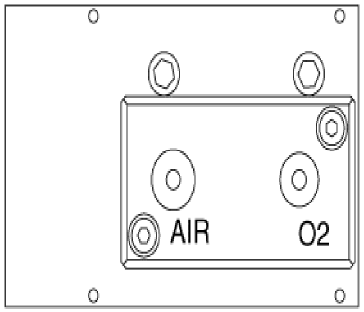


Fig. 23 Dräger gas connection block (left), FAS gas connection block (right)

3.2 Parallel mixer

The parallel mixer is a fast, electrically controllable proportional valve for gas flows between 5 and 180 L/min at supply pressures of 3 to 6 bar. Partial flows of less than 5 L/min are pulsed at a constant flow of 5 L/min. The supply gases compressed air (AIR) and oxygen (O2) available at the parallel mixer have a supply pressure of 2.7 bar to 6 bar. The parallel mixer mixes the two gases in accordance with the set parameters. The parallel mixer supplies the inspiratory gas to the patient.

The parallel mixer consists of the following components:

- Mixer connection block
- 1 cartridge valve with displacement sensor system for compressed air (AIR)
- 1 cartridge valve with displacement sensor system for oxygen (O2)
- 2 supply pressure sensors measuring the inlet pressure of the supply gases

The HPSV Controller PCBs control the parallel mixer electrically. The control signals are transmitted to the parallel mixer via the Pneumatic Motherboard PCB and the Pneumatic Controller PCB.

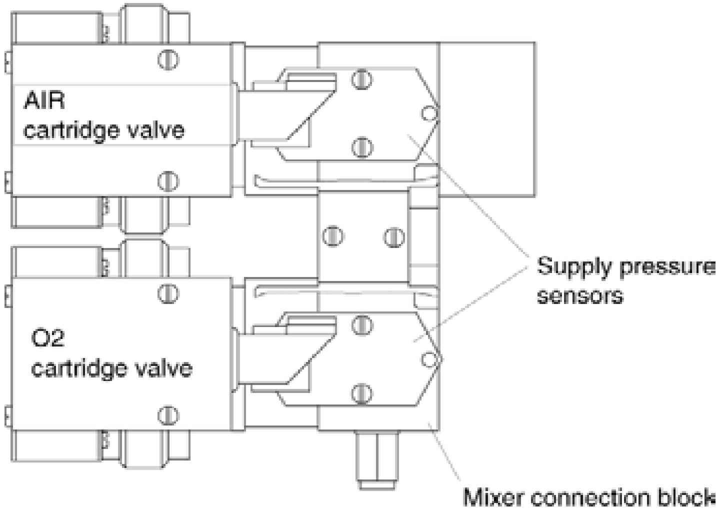


Fig. 24 Parallel mixer

3.2.1 Mixer connection block

The two cartridge valves are mounted to the mixer connection block. The inspiratory gases in the mixer connection block are supplied to the respective cartridge valve. The respiratory gas available at the outlet of the cartridge valves is mixed in the mixer connection block and supplied to the inspiratory unit.

3.2.2 Cartridge valves (HPS valves O2 and AIR)

The cartridge valve (HPS valve = HPSV = high-pressure servo-valve) supplies a defined amount of gas to the patient in accordance with the preset adjustment parameters for e.g. inspiration, trigger pressure, leak flow compensation.

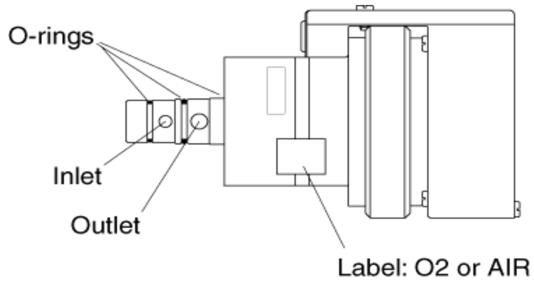


Fig. 25 Cartridge valve (HPS valve O2; HPS valve AIR)

During expiration the supply gas is available at the cartridge valve and at the supply pressure sensor In the cartridge valve the ball “A“ is pressed into the valve seat “B“; this action closes the cartridge valve (see the following Figure).

During inspiration, the drive system applies a current to the cartridge valve. The drive system is equipped with a coil working according to the principle of a moving coil of the type used e.g. in loudspeakers. The plunger is deflected in proportion to the supplied current and

pushes ball “A“ out of valve seat “B“. This causes an annular gap. The cartridge valve opens and gas flows to the patient.

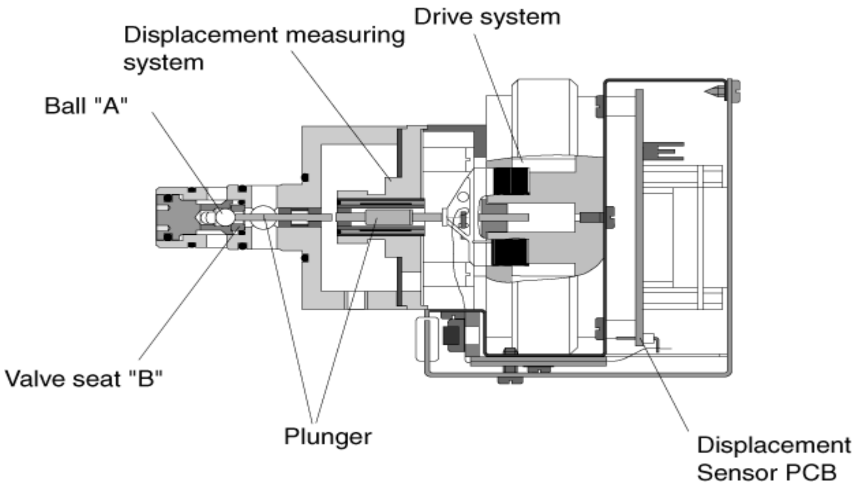


Fig. 26 Sectional view of the cartridge valve

Consequently, the size of the annular gap determines the gas flow. The annular gap between the ball and the valve seat is determined by the deflection of the plunger (i.e., by the displacement of the ball from the valve seat). The deflection is measured and controlled by a displacement measuring system. A supply pressure sensor at the cartridge valve measures the supply pressure of the gas to be dosed. The supply pressure at the cartridge valve is also used in the calculation of the gas flow. Twice the pressure for the same width of gap will produce twice the flow.

A larger width of gap (annular gap) or a higher supply pressure results in a higher flow.

The flow is determined indirectly by the displacement signal and the supply pressure. The cartridge valves supply a flow of 5 to 180 L/min. The plunger displacement depends on the supply pressure. The supply pressure is between 3 and 6 bar absolute.

For a flow requirement of 120 L/min and a supply pressure of 5 bar the displacement will be approx. 0.2 mm. For a flow requirement of 120 L/min and a supply pressure of 1.5 bar the displacement will be approx. 0.6 mm.

As the parallel mixer must permanently operate with high precision over the full flow range, it is measured and the data (non-linearity) are stored in an EEPROM on the Displacement Sensor PCB.

Therefore no calibration is required when the cartridge valves are replaced. The cartridge valves must not be interchanged since they are specifically dimensioned and fitted for each individual gas.

3.2.3 Displacement sensor system

The displacement sensor system measuring the position of the plunger in the valve is integrated in the cartridge valve. The displacement sensor system consists of the displacement measuring system and the Displacement Sensor PCB.

The displacement measuring system is a differential transformer. The a.c. voltage applied to the primary winding of the transformer has a frequency of approx. 1 MHz. The two secondary windings are switched such that their output voltages balance out. If the ferrite core (plunger of the cartridge valves) moves in the differential transformer, the output voltage of the displacement sensor system will change.

As the displacement output signal is not linear to the gas flow, the characteristic of the cartridge valve is measured and stored in the EEPROM. The micro-controller on the HPSV PCB thus balances the non-linearity of the cartridge valve.

The two circuits of the cartridge valves of parallel mixers are operated asynchronously in parallel (AIR, O2). To avoid beat interferences, the frequencies of the two oscillators must differ by a minimum of 200 kHz. Therefore the two cartridge valves have two different frequencies. The cartridge valves are measured at a special test stand.

3.2.4 Supply pressure sensors

The supply pressure sensors are calibrated to absolute pressure (0 bar). They measure the inlet pressure of the supplied gas. The supply pressure sensor is fitted with a P/U converter generating a pressure-dependent output voltage.

Measuring range	0 – 7 bar
Sensitivity	1.58 V/bar 8 mV/bar
Offset voltage	300 mV 30 mV

The supply pressure sensors are linked via a flex-strip to the Displacement Sensor PCB. The Displacement Sensor PCB is installed in the cartridge valves.

3.2.5 Airway pressure sensors

The pressure sensor mount comprises the airway pressure sensors S6.1 for the inspiratory side and S6.2 for the expiratory side. During inspiration, S6.1 monitors the airway pressure “high“ (Paw high) and the airway pressure “low“ (Paw low).

Measuring range	140 mbar
Sensitivity	36.5 mV/mbar 0.3 mV/mbar

Offset voltage	1.74 V 0.04 V

Calibration of the airway pressure sensors

The solenoid valves Y6.1 and Y6.2 expose the relevant airway pressure sensors to atmospheric pressure at specific time intervals, consequently, the airway pressure sensors are automatically calibrated. The airway pressure sensors S6.1 and S6.2 are zero-calibrated every 3 minutes. (Calibration of the possible electronic zero drift). To do so, the solenoid valves Y6.1 and Y6.2 are subsequently exposed to atmospheric pressure and the airway pressure sensors automatically calibrated.

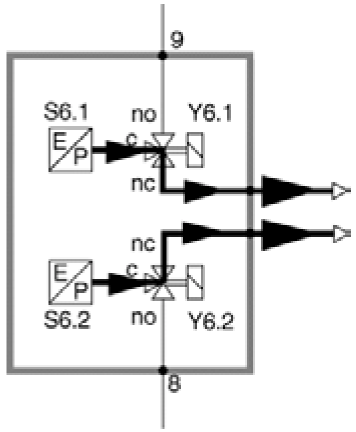


Fig. 27 Function diagram of the airway pressure sensors

3.3 Inspiration block

The safety valve D3.3 limits the pressure in the inspiratory line to 100 mbar max.

In the event of compressed air failure or mains voltage failure the pneumatically controlled emergency air valve Y3.1 will open so that the patient can breathe ambient air passing the filter F3.1. The non-return valve D3.1 prevents rebreathing of the air through the inspiratory line. The spring-loaded non-return valve D3.2 allows pressure to drop if valve Y3.1 opens.

In the case of emergency air spontaneous breathing the patient can exhale through the expiratory valve Y5.1 on account of the spring loading (5 mbar) thus preventing rebreathing.

The inspiration block is provided with the plug-in connection for the oxygen sensor.

The restrictor R1.2 limit the drug nebulizer flow to 9 L/min.

3.3.1 Emergency air

If the gas supply or the voltage supply fails, the emergency air valve Y3.1 will no longer be controlled. The patient can breathe spontaneously through filter F3.1, non-return valve D3.1 and emergency air valve Y3.1.

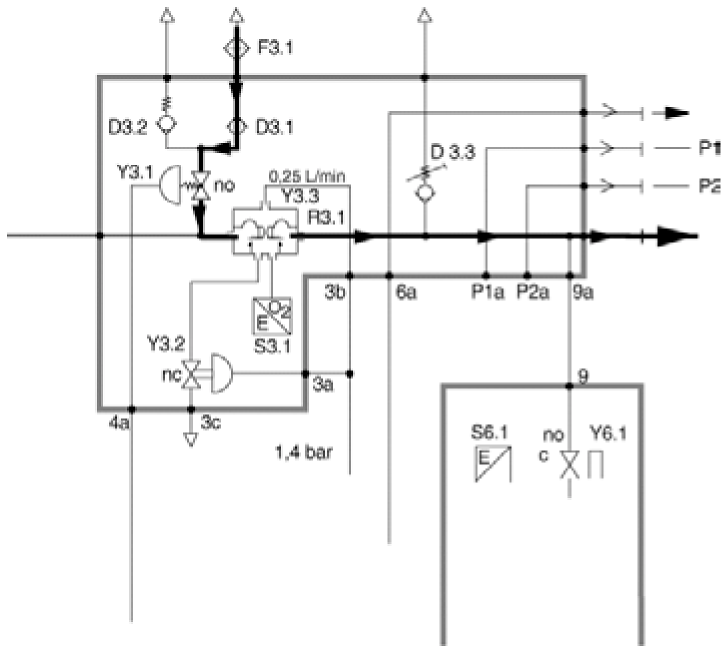


Fig. 28 Emergency air function diagram

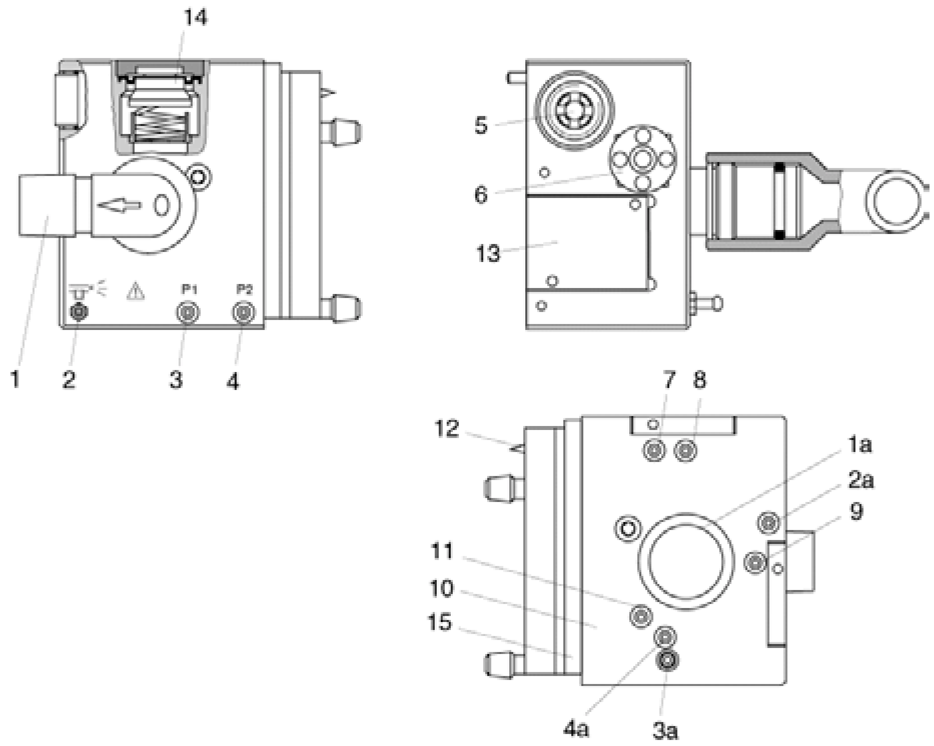


Fig. 29 Inspiration block

Legend

1-1a	Patient connection (inspiration)
2-2a	Nebulizer connection
3-3a	Esophageal pressure P1
4-4a	Esophageal pressure P2

5	10 mbar pressure relief valve D3.2
6	100 mbar pressure relief valve D3.3 (adjustable; NOTE: until middle of ’96 valve slot milled in the block, after ’96 separate piece screwed onto the block)
7	Emergency pressure relief mechanism control
8	Pressure measurement (inspiration)
9	O2 calibration control
10	O2 sensor chamber (behind the O2 amplifier)
11	O2 calibration purge flow outlet
12	Emergency air non-return valve D3.1 in O2 amplifier
13	O2 calibration diaphragm lattice Y3.3 with R3.1
14	Valve Y3.1
15	O2 amplifier

3.4 Patient system

The expiratory gas flows from the patient directly to the expiratory valve Y5.1. The copper measuring line at the 8a connection has a germicidal effect and connects the expiratory side to the pressure sensor S6.2.

The expiratory valve has a transmission ratio of approx. 1:1. The non-return valve D5.1 allows flow in one direction only and makes sure that gases do not travel backwards. The flow sensor S5.1 measures the expiratory flow.

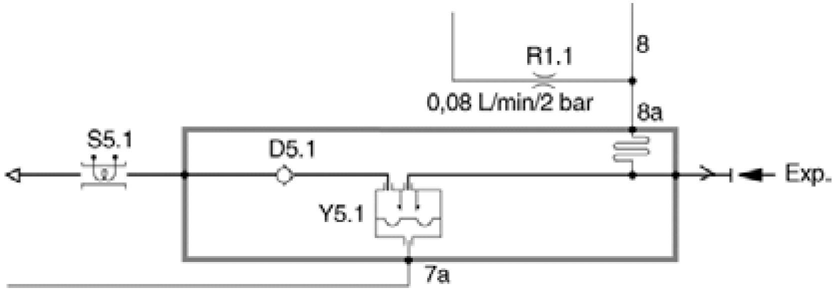


Fig. 30 Patient system function diagram

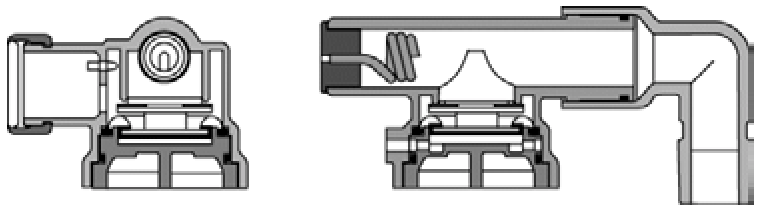


Fig. 31 Sectional view of the patient system

The ratio between the control pressure at the 7a connection of the PEEP/PIP valve and the resulting pressure at the expiratory port is linear to the following values:

Control pressure of 3 mbar => expiratory pressure of 0 mbar

Control pressure of 33 mbar => expiratory pressure of 33 mbar

3.4.1 Patient system with RS water trap

The water trap avoids flow measurement faults caused by water droplets. Such faults may occur if the water traps on the ventilation hoses are not positioned at the lowest possible point. In this case the condensation water is collected in the water trap of the patient system.

The collector jar of the water trap can be removed during operation. The opening to the patient system is sealed automatically.

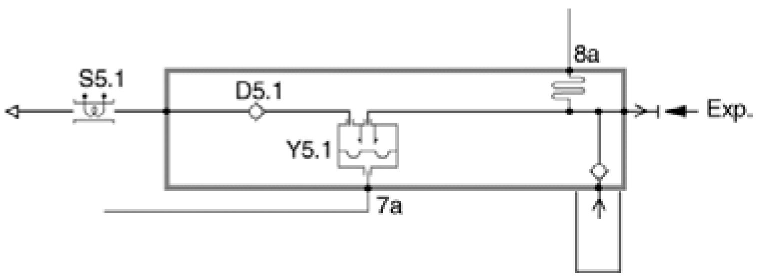


Fig. 32 Function diagram of the patient system with water trap

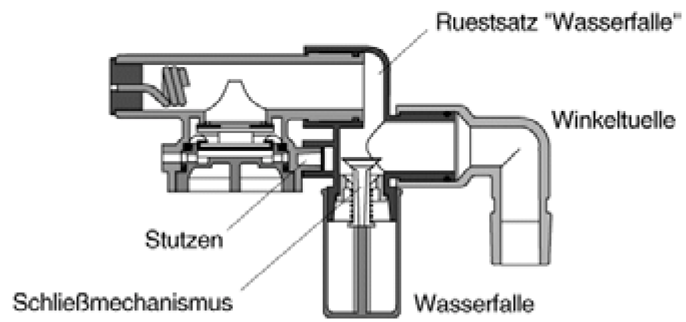


Fig. 33 Sectional view of the patient system with water trap

3.5 PEEP/PIP valve

The PEEP/PIP valve Y4.1 consists of a diaphragm valve acting as a flow-control device and the linear drive whose plunger closes the diaphragm valve. A coil drives the PEEP/PIP valve Y4.1. The preset ventilation defines the settings. A computer program processes these settings, and the coil is driven by an appropriate current. The PEEP valve opens and adjusts a pressure proportional to the adjusted electric current (Note: 0 mA will correspond to –1 mbar, 500 mA to 120 mbar).

The PEEP/PIP valve Y4.1 controls the expiratory valve Y5.1 in the patient system via a servo-line. The solenoid valve Y1.3 supplies control gas to the

restrictor R4.1 and to the PEEP/PIP valve Y4.1. The non-adjustable restrictor R4.1 is set to a flow of 3.5 L/min.

Depending on the PEEP setting the plunger coil is activated causing an appropriate servo-pressure to be applied to the diaphragm of the expiratory valve.

The software compares the preset and measured airway pressures. This comparison is a measure of the Pneumatic Controller PCB's control action on the PEEP/PIP valve. The PEEP/PIP valve is calibrated to the electronics. The calibration data are stored on the Pneumatic Controller PCB.

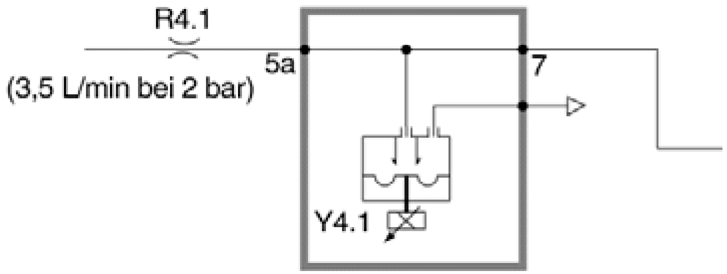


Fig. 34 PEEP valve function diagram

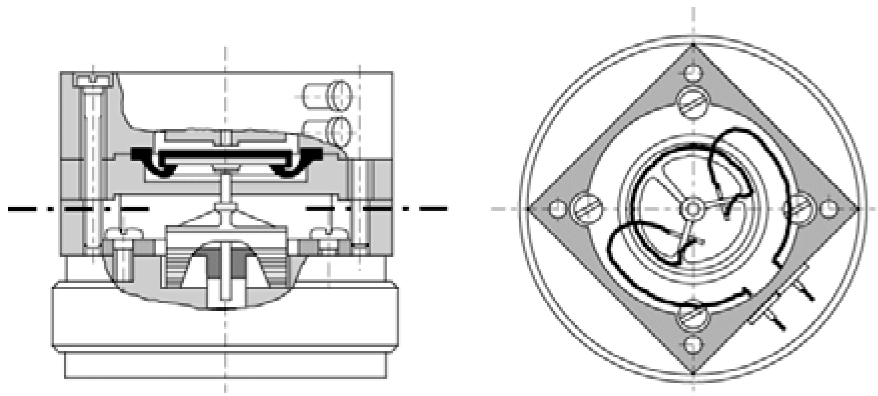


Fig. 35 Section view of the PEEP valve

4 Theory of operation

4.1 AIR supply

AIR flows through the filter F1.1 passing the non-return valve D1.1 reaching the mixer and flow control unit (pressure sensor S2.1 and HPSV Y2.1). At the same time, the gas flows to the 3/2-way solenoid valve Y1.1 via the pressure regulator DR1.1 which is set to 2 bar. From here the gas flows through the 3/2-way solenoid valve Y1.3 to the emergency air valve Y3.1 which closes. Furthermore, the gas passes the restrictor R4.1 to reach the PEEP/PIP valve Y4.1 and from there – depending on the setting – to the expiratory valve Y5.1. Finally, the gas passes the restrictor R1.1 to flow to the expiratory pressure sensor S6.2 connecting line on the patient side. At this point, expiratory humidity is prevented from reaching the pressure sensor S6.2.

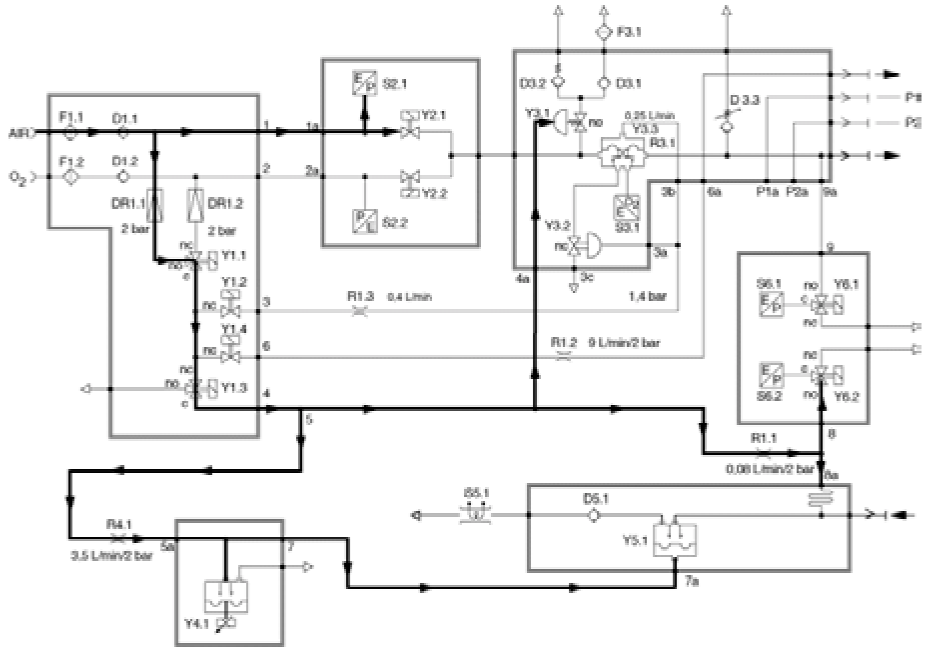


Fig. 36 AIR supply function diagram

4.2 O2 supply

O2 flows through the filter F1.2 passing the non-return valve D1.2 reaching the mixer and flow control unit (pressure sensor S2.2 and HPSV Y2.2). At the same time, the gas flows to the 3/2-way solenoid valve Y1.1 via the pressure regulator DR1.2 which is set to 2 bar.

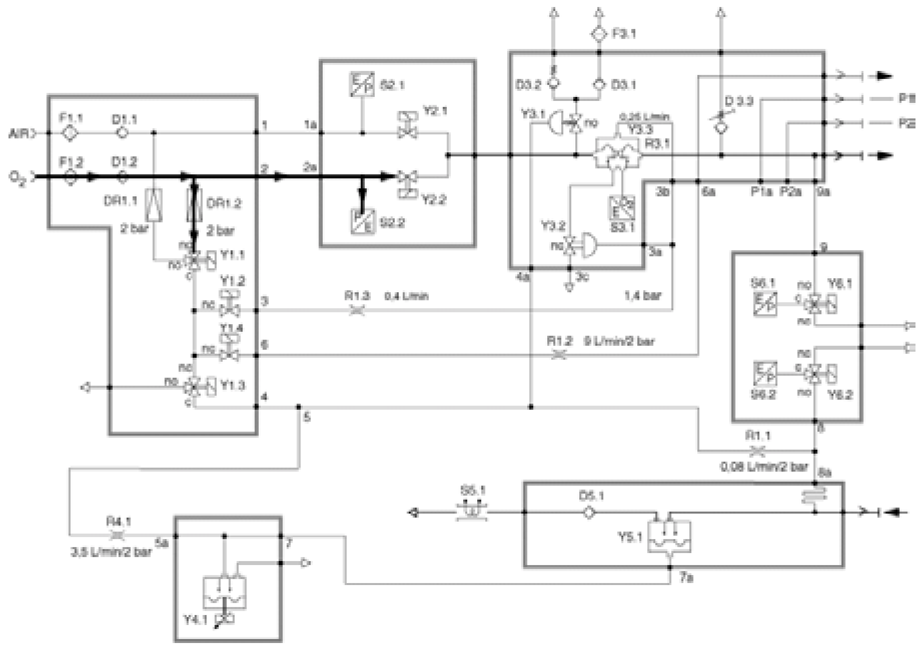


Fig. 37 O2 supply function diagram

4.2.1 O2/AIR changeover valve

The 3/2-way solenoid valve Y1.1 switches under the following circumstances:

- If the “AIR“ supply fails
- When the O2 sensor is calibrated
- When the nebulizer function (depending on FiO2 setpoint) is triggered

If these conditions are given, the servo-system will be supplied with O2.

4.3 Inspiratory phase

Depending on the settings (O2 concentration, inspiratory volume, frequency, Ti, inspiratory flow, inspiratory pressure) the cartridge valves (HPSVs Y2.1 and Y2.2) open. The gas flows to the patient through the inspiratory port. At the same time, gas flows to the O2 sensor S3.1 and to the safety valve D3.3; from there, it flows through the 3/2-way solenoid valve Y6.1 to the inspiratory pressure sensor S6.1.

The safety valve D3.3 is fixed to 100 mbar and serves as an additional safety device in the event of a complete failure of the electronic control.

When calibrating the O2 sensor S3.1, valve Y3.3 disconnects the sensor from the inspiratory gas. The O2 sensor S3.1 is supplied with 100% O2 from the valve Y1.2, the restrictor R1.3, the restrictor R3.1 and the valve Y3.2. The O2 concentration and the flow will not be influenced by the inspiratory gas.

The pressure sensors S6.1 and S6.2 monitor the inspiratory pressure. During the entire inspiratory time the PEEP/PIP valve Y4.1 provides pressure to the expiratory valve Y5.1.

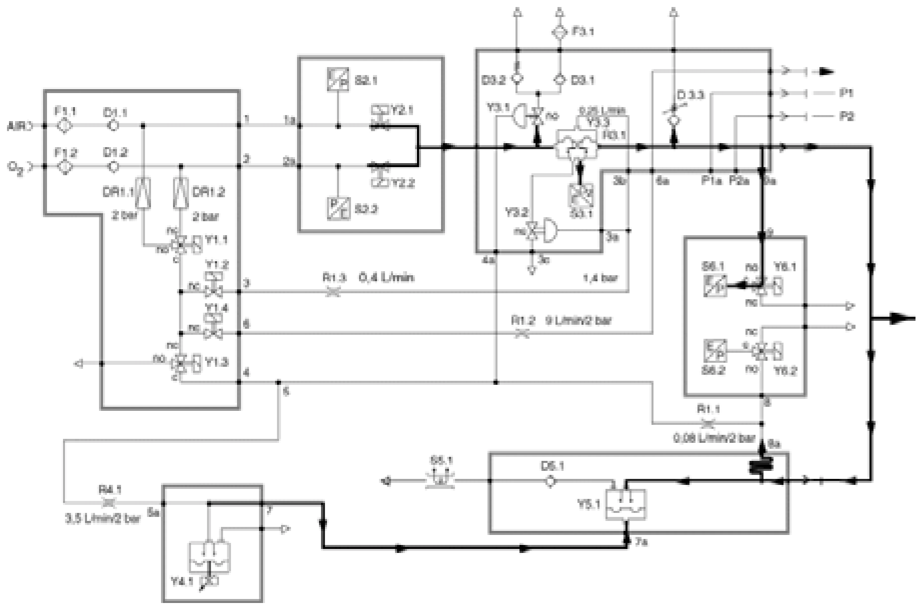


Fig. 38 Inspiratory phase function diagram

4.4 Paw high alarm limit

In case the “Paw high“ alarm limit is exceeded during inspiration, the HPSV Y2.1 and Y2.2 interrupt the gas flow. The PEEP/PIP valve Y4.1 is switched to expiration and the patient can exhale.

4.5 Emergency pressure relief mechanism (safety valve)

In case the “Paw high“ alarm limit is exceeded by 5 mbar, an additional safety valve, the so-called “emergency pressure relief mechanism“ Y1.3 will open. As a result, the emergency air valve Y3.1 opens and the pressure is vented through the non-return valve D3.2.

4.6 Expiration

At the start of expiration the cartridge valves (HPSV Y2.1 and Y2.2) are closed. No gas flows to the patient. The PEEP/PIP valve Y4.1 is switched to the set PEEP value. The expiratory valve Y5.1 is also relieved and the patient can exhale through the non-return valve D5.1 and the flow sensor S5.1. The flow sensor S5.1 measures the expiratory flow.

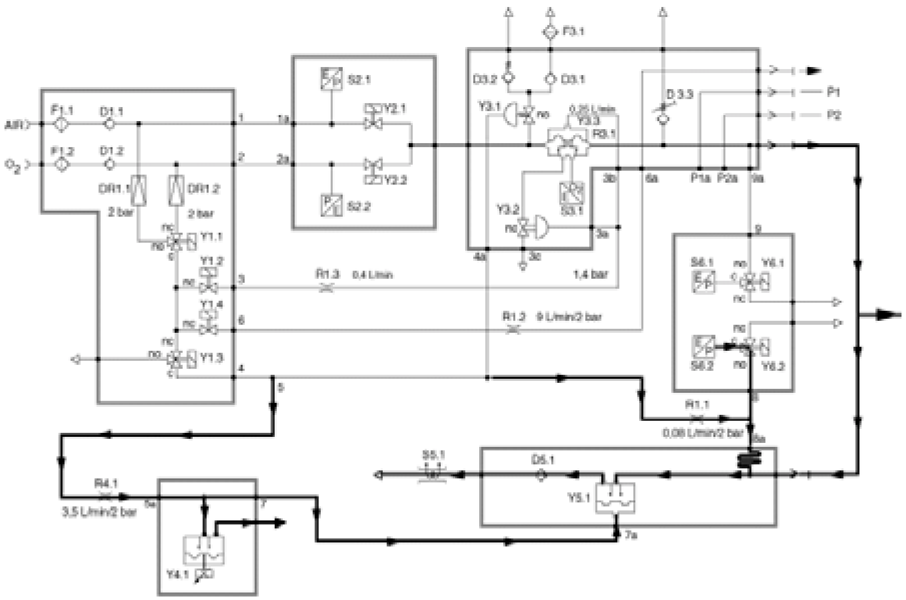


Fig. 39 Expiratory phase function diagram

4.6.1 Drug nebulizer

After pressing the “drug nebulizer“ button, the drug nebulizer is switched on for 30 minutes. At the same time, the solenoid valve Y1.4 switches through in the flow-active inspiratory phase. The restrictor R1.2 supplies the drug nebulizer with drive gas. At the end of the inspiratory gas supply phase, the solenoid valve Y1.4 also switches back. The minute volume remains constant while the flow setting is being corrected. After completion of the drug nebulization the flow sensor S5.1 is automatically glowed clean.

Note: the drug nebulizer needs a minimum inspiratory flow of 16 L/min.

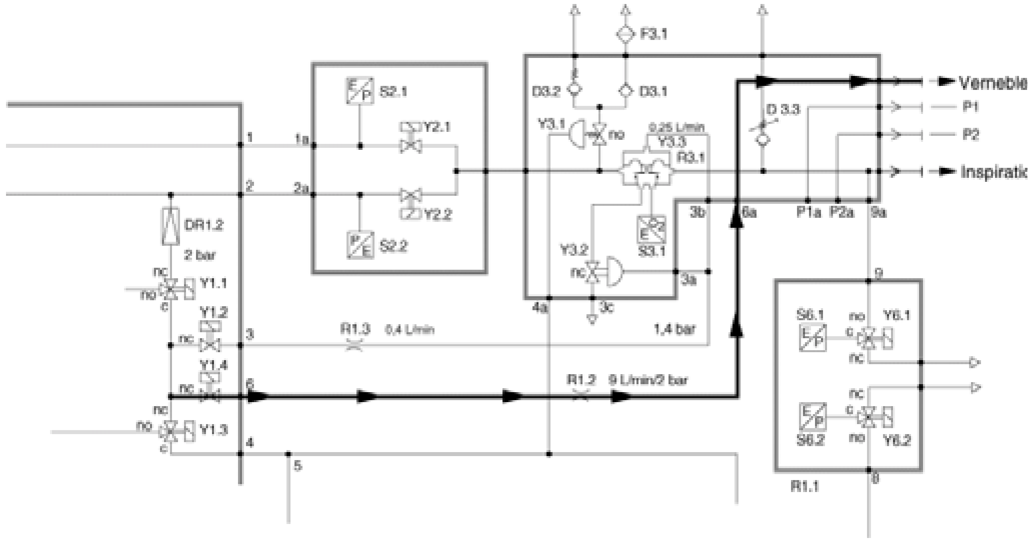


Fig. 40 Nebulizer function diagram

5 Gas mixture

One cartridge valve (HPSV) each controls the air flow or the oxygen flow, directly from the supply lines. Both sub-flows are joined in the parallel mixer and then supplied to the inspiration block. Depending on the set oxygen concentration (FiO2: 0.21 to 1.00), the total flow to be metered is split into an “AIR“ sub-flow and an “oxygen“ sub-flow. Sub-flows of less than 5 L/min are no longer metered continuously, but in pulses lasting at least 8 ms and with a constant flow value of 5 L/min. This results in a pulse/pause ratio that corresponds to the sub-flow value.

5.1 Correcting the oxygen cartridge valve

Corresponding to its operating principle, the cartridge valve (HPSV) meters a mass flow. Owing to the differing gas density values of the compressed air and the oxygen, different volume flows would therefore be applied if these values were not corrected.

Owing to the different gas density values, the portion of the inspiration flow demanded of the oxygen cartridge valve is therefore increased by 5%.

5.2 Dependence on the supply pressure

With regard to the gas supply, the operating range of the machine is specified from 2.7 bar to 6 bar gauge pressure. The machine monitors this operating range with the aid of the absolute pressure sensors on the cartridge valves on the basis of the following criteria:

- Supply pressure always higher than 1.2 relative/absolute
- At no flow, supply pressure higher than 2.5 bar relative

At low supply pressures (below 3 bar gauge pressure), the cartridge valve can no longer apply high flows without errors, i.e. the actually supplied flow is less than the demanded flow. The inspiratory flow must be limited for reasons of flow accuracy and thus also for oxygen concentration accuracy reasons.

Prior to the start of an inspiration, the maximum inspiratory flow for spontaneous inspiration of the cartridge valve is defined on the basis of the measured supplied gauge pressure:

6 Function diagram

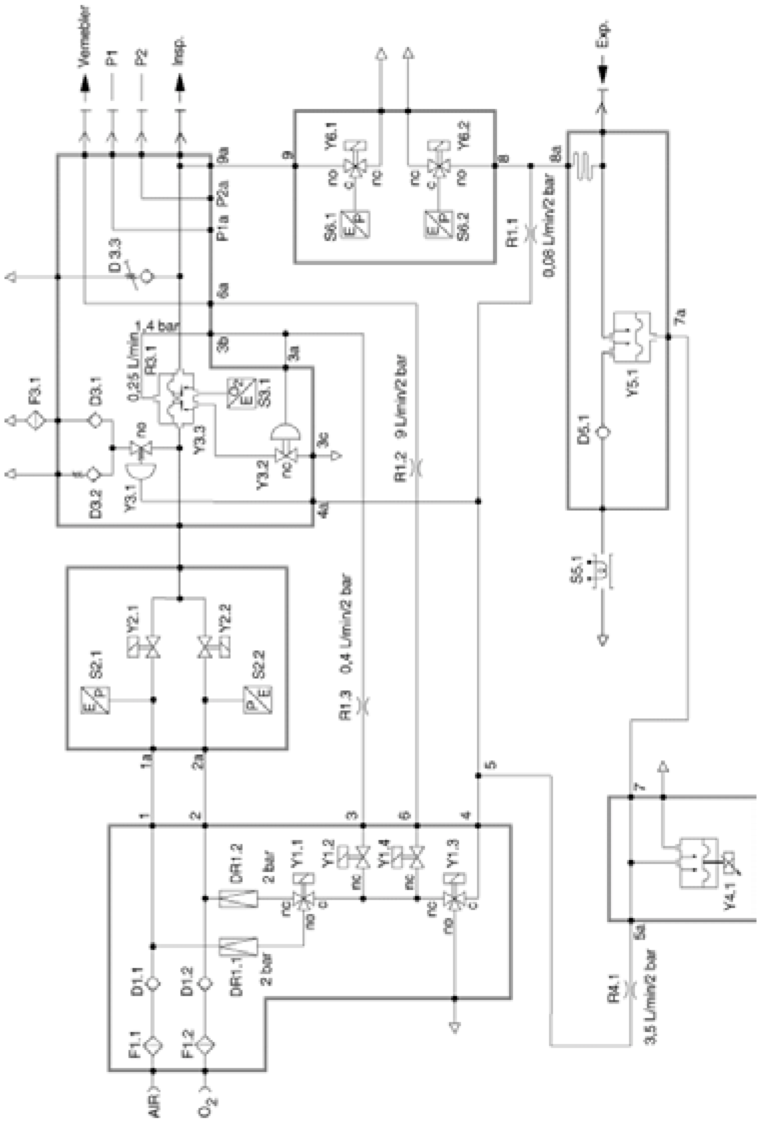


Fig. 41 Function diagram

Legend

AIR	Air connection	Y3.1	Emergency air valve
O2	Oxygen connection	Y3.3	Inspiratory valve
		Y4.1	PEEP/PIP valve
F1.1	Filter	Y5.1	Expiratory valve
F1.2	Filter	Y6.1	3/2-way solenoid valve, insp.
F3.2	Filter	Y6.2	3/2-way solenoid valve, exp.
D1.1	Non-return valve	S2.1	AIR pressure sensor (HPSV)
D1.2	Non-return valve	S2.2	O2 pressure sensor (HPSV)
D3.1	Non-return valve	S6.1	Inspiratory pressure sensor
D3.2	Non-return valve 10 mbar	S6.2	Expiratory pressure sensor
D3.3	Non-return valve 100 mbar	S3.1	O2 sensor
D5.1	Non-return valve	S5.1	Flow sensor

DR1.1	AIR pressure regulator	R1.1	Restrictor 0.08 L/min/2bar
DR1.2	O2 pressure regulator	R1.2	Restrictor 9 L/min/2bar
		R1.3	Restrictor 0.4 L/min/2bar
		R3.1	Restrictor (hole in the diaphragm in Y3.3) 0.25 L/min/1.4 bar
		R4.1	Restrictor 3.5 L/min/2bar

Y1.1 3/2-way solenoid valve, O2/AIR

Y1.2 3/2-way solenoid valve calibration O2 sensor

Y1.3 3/2-way solenoid valve, venting

Y1.4 3/2-way solenoid valve, nebulizer

Y2.1 AIR HPSV (high-pressure servo-valve) parallel mixer

Y2.2 O2 HPSV (high-pressure servo-valve) parallel mixer